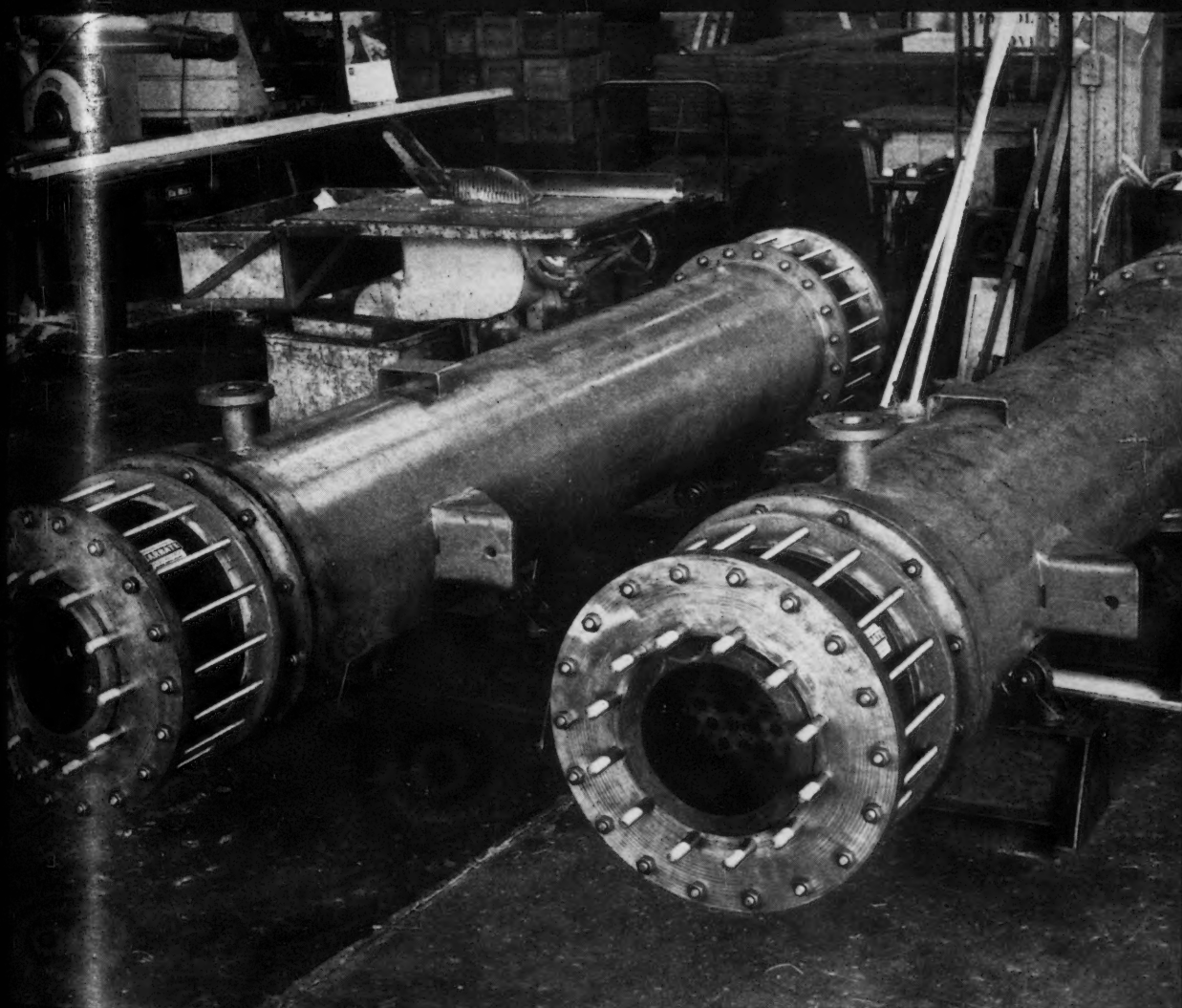
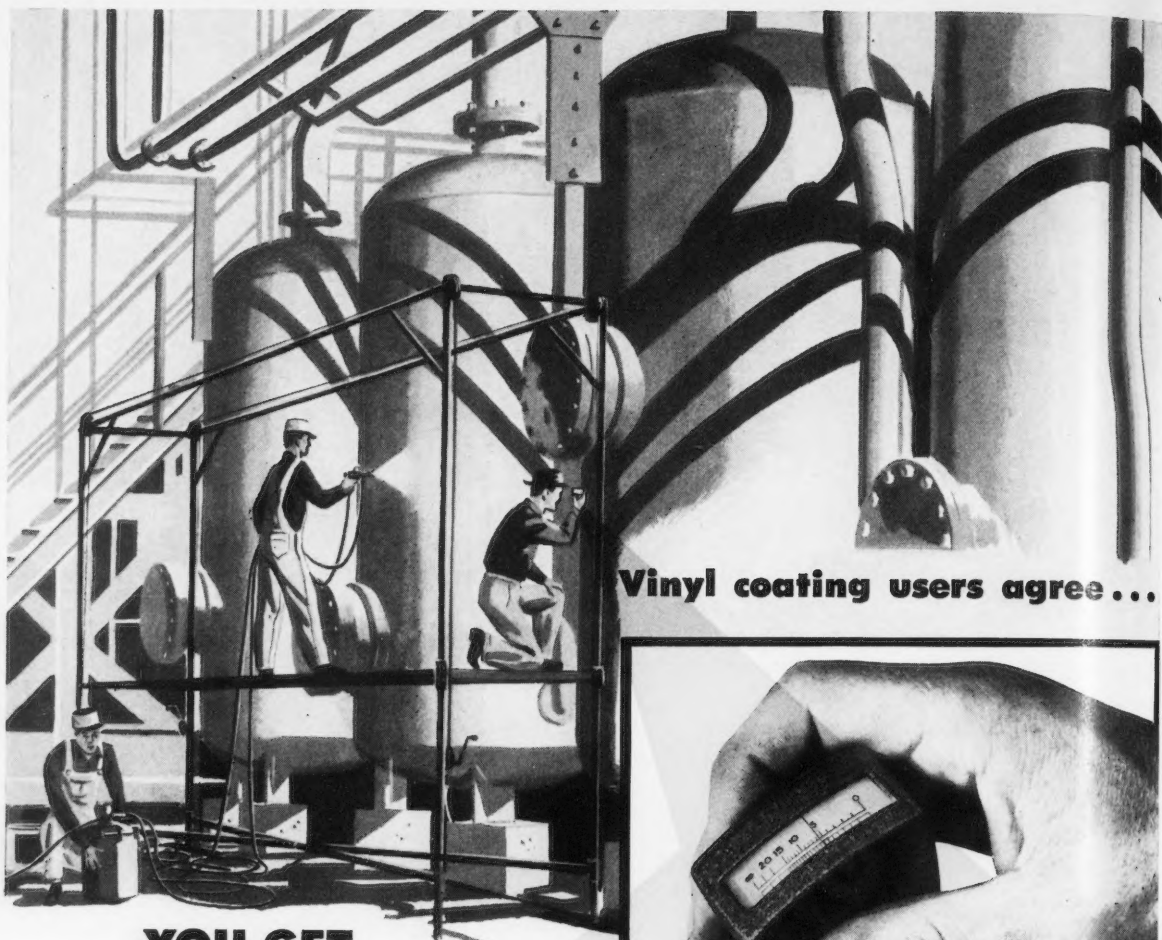


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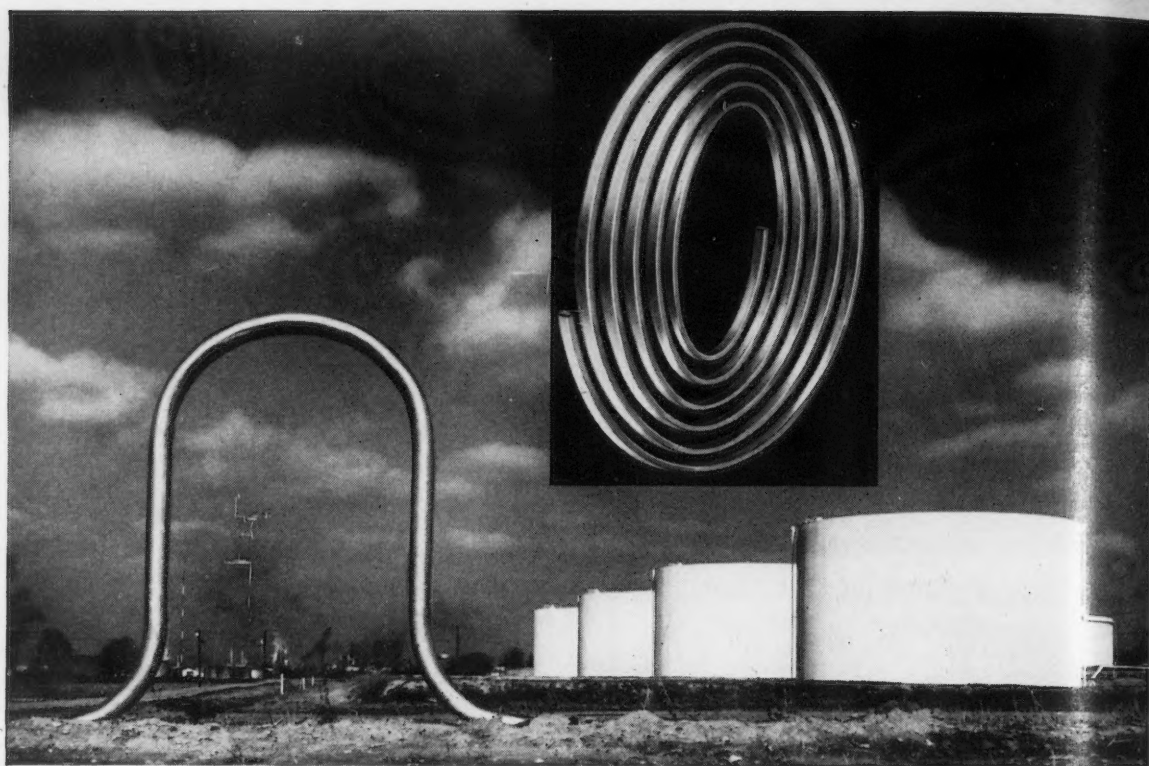
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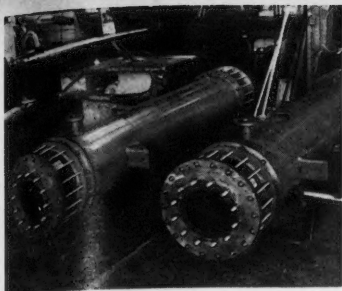
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No. 9

CONTENTS

Directory of NACE Regional and Sectional Officers.....	iv, v, vi
Directory of NACE Technical Committees.....	viii, ix
Officers and Directors, National Association of Corrosion Engineers.....	xvi

TECHNICAL SECTION

Topic of the Month—High-Silicon Cast Iron Tested for Use With Impressed Currents By Walter A. Luce.....	267
Pitting Corrosion Characteristics of Aluminum—The Influence of Iron and Silicon By P. M. Aziz and Hugh P. Godard.....	269
Relation of Corrosion to Business Costs By Aaron Wachter.....	273
Corrosion of Bronze Oil-Sealing Sleeves in Centrifugal Gas Compressors By Edward C. Greco.....	279
Raised Earth Potential By Robert H. Pope.....	284
Radiometric Study of Phosphate Coatings Formed on Steel in Pretreatment Baths By Thomas F. Boyd, Michael Galan and Leonard Markowitz.....	285
Corrosion Control in Gas Lift Wells By D. A. Shock and J. D. Sudbury.....	289
Oxidation of Plain, Alloyed and Ductile Irons at 1300 Degrees F By J. A. Cameron..... Discussion: James T. Dwyer, Jr., K. D. Mills, Page 297; Replies by J. A. Cameron, Pages 297, 298.	295
First Interim Report of Technical Unit Committee T-48 on Corrosion of Cable Sheaths. Pipe-Type Cable Corrosion Protection Practices in the Utilities Industry. Publication 54.3.....	299

NACE REGIONAL AND SECTIONAL NEWS

Large Group Attends Water Flooding Talks.....	Page 1	Dallas Pipe Line Round Table Panel Named.....	Page 2
Gehant Will Speak.....	1	Permian Basin Section Meetings Scheduled.....	2
Edmonton Section Names Officers.....	1	San Francisco Bay Area Meeting Program.....	2
Tentative Program for Los Angeles Adopted.....	1	Houston Hears Thornton on Plastic Pipe.....	3
Tour of Procter & Gamble Plant Scheduled.....	1	Houston Section to Drive for Corporate Members.....	3
Short Course Calendar.....	1		

TECHNICAL COMMITTEE NEWS

Report on Vinyl Coatings Readied.....	Page 5	May Accepts T-3G Chairmanship.....	Page 7
Kahn Resigns After Completing Report.....	5	Inhibitor Screening Procedure Is Revised.....	7
T-3F Members to Give High Purity Water Session.....	5	Honnaker and Gabriel Are T-6K Officers.....	8
Twelfth Report Made on Sulfide Stress Probe.....	5	Provisions for Committee Liaison Made.....	8
		Service Reports Given on Oil Field Plastic Pipe.....	9

GENERAL NEWS OF CORROSION INTEREST

Pokorny Accepts Policy Committee Post.....	Page 2	AISE Session Set at Cleveland.....	Page 18
Library Rate Reduced.....	2	Some Instrument Congress Technical Papers Have Corrosion Connection.....	19
Chinese Science Bulletin.....	3	Aluminum Wrought Alloy Designations Revised.....	19
Chicago Technical Program Schedule Outlined.....	17	Book Reviews.....	20
85 Attend Short Course at MIT.....	17	Corrosion Meetings Calendar.....	22
Conditions Existing at Time of Fatal Titanium Explosion Are Given.....	18	New Products.....	23
		Personals.....	26

INDEX TO CORROSION ABSTRACTS

INDEX TO ADVERTISERS

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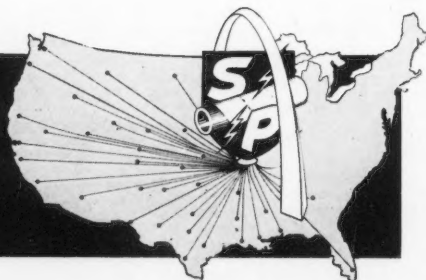
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T-5A-4 Chlorine

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T-5C-1 Corrosion by Cooling Waters (South Central Region)

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T-6C-1 Protective Coatings for Resistance to Marine Corrosion (Pacific Coast Region)

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George P. Gabriel, Vice-Chairman, Atlas Mineral Products Company, Mertztown, Pa.

T-6M Field Coating Inspection

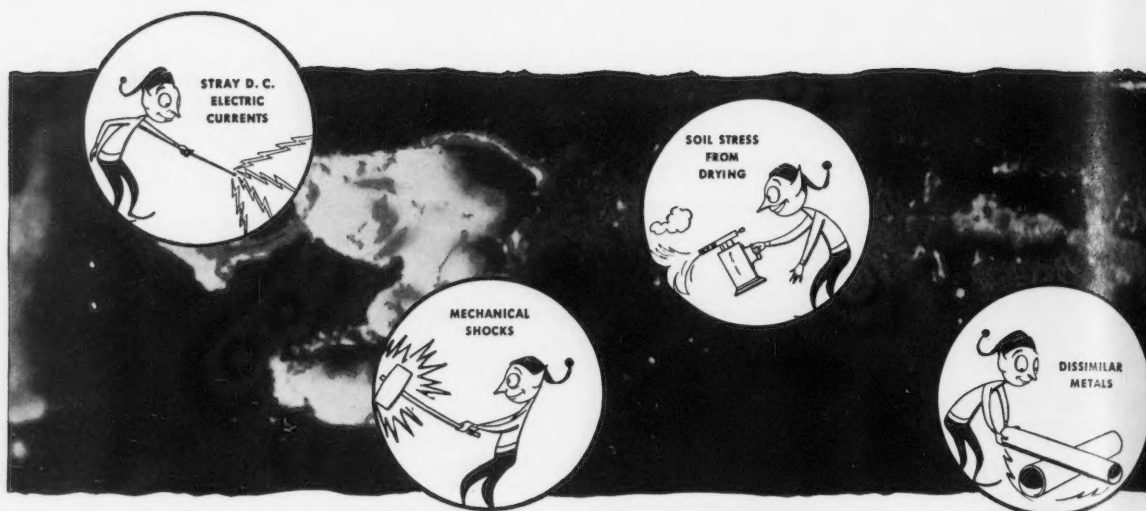
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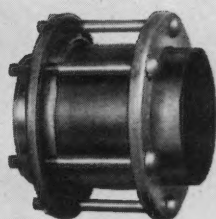
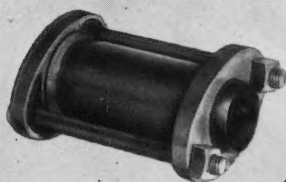
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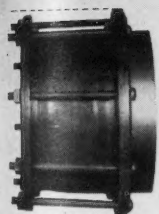
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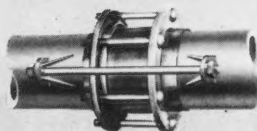
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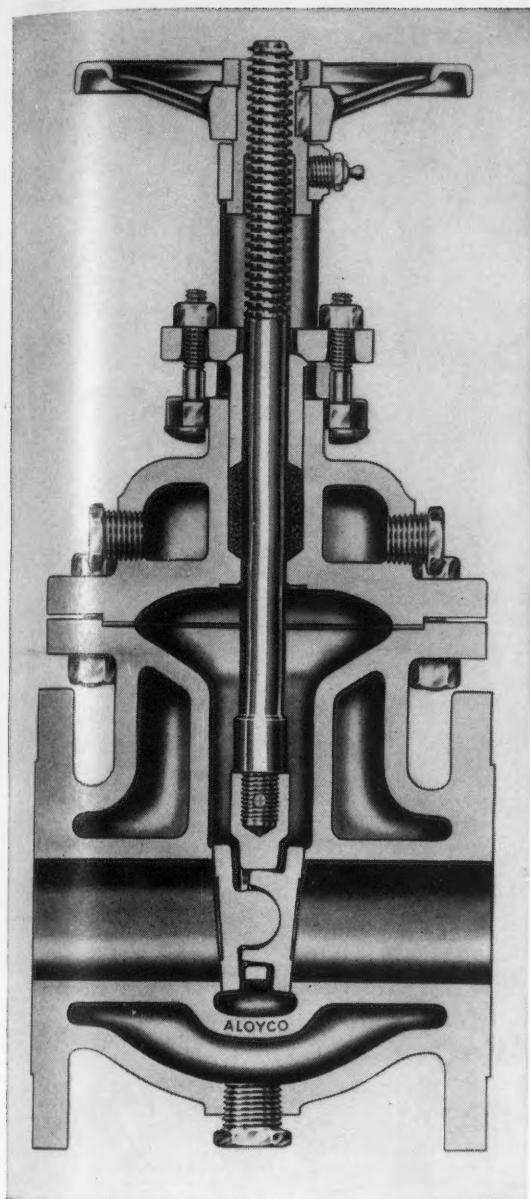
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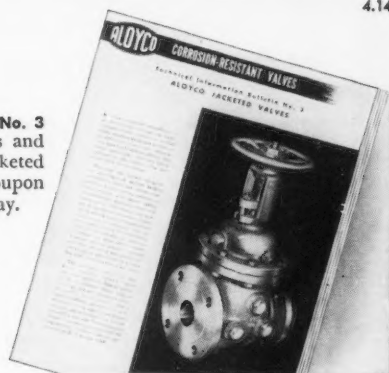
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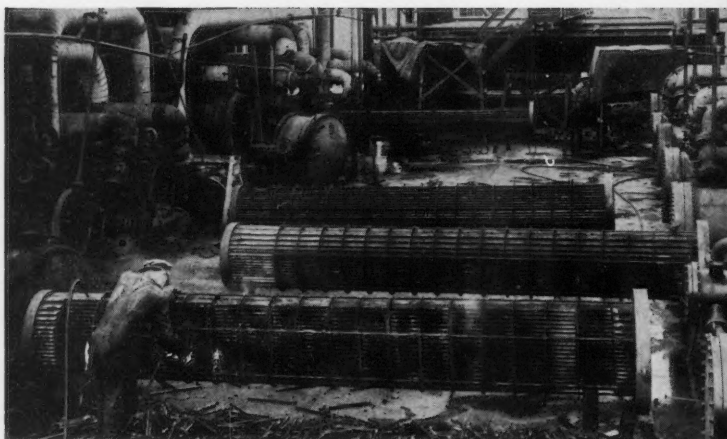
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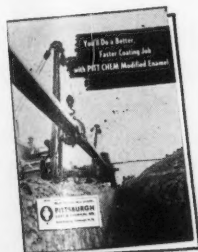


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CORROSION—September, 1954

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Topic of the Month

High-Silicon Cast Iron Tested For Use With Impressed Currents

By WALTER A. LUCE*

AN INVESTIGATION has been in progress since early 1952 to determine the merits of high-silicon cast iron as an impressed current anode material in cathodic protection installations. At the 1952 National Association of Corrosion Engineers' conference, the suggestion was first made to Technical Practices Committee T-2B (formerly TP-3) that this material might possess interesting possibilities in this application and a test program was initiated under its guidance. Information to date indicates this alloy to have great potentialities in this field.

Description of Material

The material** is a 14.5 percent silicon cast iron which possesses excellent resistance to a variety of corrosive media. Like other metals and alloys it has a dense, homogeneous structure which assures uniform properties throughout. It will neither absorb moisture nor flake and cannot become soft or lose electrical properties. Although unlike some other metals its tensile strength is relatively low and it can be broken by mechanical shock, it is still much superior to graphite in this respect. It can be produced only in castings which somewhat restricts the anode length that can be produced.

Because it is an iron-base alloy, it possesses the relatively good electrical properties common to these materials. It has specific resistance of approximately 72 ohm-centimeter at 20 degrees C. It also does not appear to have deleterious galvanic tendencies when connected with other iron-base alloys. Because it cannot be machined readily by conventional means electrical connections must therefore be made by other methods. When machining is necessary, one or more inserts of a machinable alloy can be permanently cast into the anode. It also can be brazed successfully. These techniques provide acceptable means for making electrical connections.

Abstract

Laboratory and field tests with high-silicon cast iron anodes in fresh and salt water and in earth indicate the material has promising characteristics for use as anodes in cathodic protection systems using external current sources. The material tested, Duriron, has 14.5 percent silicon. Low consumption rates at various current densities in the media listed were reported.

Test Information

Tests already completed give an indication of the resistance of the cast iron to a variety of media in which cathodic protection is needed. This includes fresh and salt water and ground installations. Fresh water tests and salt water tests were conducted in cells made from steel drums (cathode) in which the anode was centered to provide uniform current distribution. The test installation is illustrated by Figure 1. Ground bed tests were conducted by actually burying anodes in the ground at an appropriate distance from an existing pipe line. The results of these preliminary tests are given as follows:

Fresh Water—The introductory fresh water tests were conducted at a current density of 1.0 ampere



Figure 1—Laboratory electrolytic cells for testing Duriron in fresh water and synthetic sea water.

*Metallurgical Engineer, The Duriron Co., Inc., Dayton, Ohio.

**Duriron, a product of The Duriron Co., Inc.



Figure 2—Typical Duriron anodes. Two 2-inch anodes at left are designed for testing in ground and sea water applications. Special 1-inch anodes (right) have threaded inserts at each end for stringing end-to-end in fresh water applications. All anodes are 60 inches long.

per square foot in water solutions of varying pH. Hydrochloric acid and potassium hydroxide were used to adjust the pH to the desired value. The test duration in each case was one month. Results are given in Table 1.

Although the results in pH 1.5 water indicated appreciable attack, the results under the more practical conditions indicate it is relatively unaffected. Tests in other water services are currently being conducted to clarify this point. The material had no noticeable deleterious effect on the water, such as flaking, rusting or odor. Tests at another laboratory showed a low consumption rate at 10 amperes per square foot.

Sea Water—Numerous tests in barrel cells have been conducted in synthetic sea water at different current densities. Results are given in Table 2. All values are an average of two or more separate tests.

TABLE 1

Solution, pH	Duriron Consumption Rate Pounds/Ampere/Year
7.0*	Nil
10.0*	Nil
1.5	0.60
1.5	1.20

* Duplicate tests gave identical results.

TABLE 2

Current Density Amperes/Square Foot	Duriron Consumption Rate Pounds/Ampere/Year
0.50	Nil
1.00	0.58
5.00	0.31
10.00	0.91
20.00	0.95
30.00	0.97
100.00	1.46

TABLE 3

Duriron Anode Number	Test Duration, Months	Backfill Material	Average Current Density, Amperes/Square Foot	Anode Consumption, Pounds/Ampere/Year
1.....	3	Dirt	0.45	1.08
2.....	6	Coke Breeze	0.82	Nil
3.....	6	Dirt	0.50	0.28

The attack appears to be relatively uniform in all cases.

Ground Bed Tests—Limited ground bed testing in soil of 7.7 pH and 4400 ohm-centimeter resistance showed the results given in Table 3.

Present Program

In addition to the laboratory tests being conducted in salt and fresh water and in soil applications, numerous trial anodes have been supplied interested organizations to evaluate the alloy under field conditions. The type anodes used are illustrated in Figure 2. More than 150 of these anodes are now in test and preliminary information on these tests should be available for consideration at the 1955 NACE conference.

Influence of Iron and Silicon

Pitting Corrosion Characteristics of Aluminum*

By P. M. AZIZ and HUGH P. GODARD*

Introduction

A PREVIOUS publication¹ has dealt with the influence of manganese and magnesium on the pitting characteristics of aluminum in the purity range 99.5 to 99.99 percent Al. The present work deals with the effect of iron and silicon on the pitting characteristics of aluminum of 99.5 and > 99.99 percent purity.

Unpublished qualitative work carried out in this laboratory by the authors has shown that the addition of iron and silicon increases the probability and rate of pitting of super purity aluminum. As these are the major impurities present in commercial purity aluminum, the present work was undertaken to obtain quantitative information on their influence. Because certain other trace elements which are present in commercial purity ingot and absent in super purity metal might influence the effects of iron and silicon, or have an influence of their own, two series of alloys were studied; these were prepared by adding varying amounts of iron and silicon to ingot of > 99.99 and 99.75 percent purity respectively.

The pitting characteristics of the alloys were evaluated by determining the pitting probabilities and pitting rates as described in a previous publication.¹

Description of Material

The detailed composition of the super purity and commercial purity aluminum stocks is given in Table 1.

These analyses are typical for smelter ingot produced in various parts of the world. Different sources of bauxite and raw materials do reflect some slight variation in the final metal.

From this table it is apparent that the commercial purity alloys will have larger amounts of certain impurities than the super purity alloys. These are:

- Ga — at least nine times as high
- V — at least five times as high
- Ti — at least four times as high
- Mn — at least twice as high
- Cu — about twice as high
- Ni — slightly greater
- Mg, Zn, Cr, Na, Pb, Sn, Ca, Zr, B — no detectable difference

The composition of the alloys prepared and tested is given in Tables 2 and 3. The alloys were prepared by introducing iron and silicon into aluminum melts in the form of hardeners prepared from > 99.99 percent aluminum, electrolytic iron and high purity elemental silicon.

Abstract

This work was undertaken to determine the influence of iron and silicon upon the pitting characteristics of aluminum. Iron and silicon in amounts from 0.05 to 0.7 percent, alone and in various combinations was added to commercial purity (99.75 percent Al) and super purity (>99.99 percent Al) aluminum. The addition of iron at any level increases the pitting probability of super purity aluminum whereas no significant increase occurs for the commercial purity aluminum. The addition of silicon to super purity aluminum in amounts of 0.3 percent and greater increases the pitting probability whereas no significant increase occurs for commercial purity aluminum. The probability of pitting of commercial purity aluminum is 2.5 times that of the super purity aluminum at corresponding iron and silicon levels. The addition of iron and/or silicon increases the rate of pitting of super purity aluminum but has little effect on the rate of pitting of commercial purity aluminum.

Ten pound melts of each alloy were prepared and cast into two 2 x 4 x 6-inch ingots. The ingots were scalped and then rolled into sheet by first soaking at 550 degrees C for three hours, hot rolling to 0.250-inch and then cold rolling to a nominal thickness of 0.025-inch. Before use the sheet was fully annealed by heating for 0.5 hour at 450 degrees C.

Experimental Procedure

Experimental procedures employed were those described in a previous publication.¹ Briefly they were as follows:

1. Determination of Pitting Probabilities

The metal in the form of fully annealed 4½-inch by 6-inch sheet panels was vapor degreased, etched in 85 percent phosphoric acid at 70 degrees C for two minutes, washed in running tap water for 20 minutes and rinsed in three changes of distilled water. The panels were then air dried for two hours and ruled

TABLE 1—Detailed Composition of Ingot Tested

Percent	Super Purity	Commercial Purity
Al*	> 99.99	99.75
Cu	0.002	0.004
Fe	0.004	0.11
Mg	< 0.001	< 0.001
Mn	< 0.002	0.002
Ni	< 0.001	0.001
Si	0.001	0.10
Ti	< 0.001	0.004
Zn	< 0.002	< 0.002
Cr	< 0.002	0.002
Na	0.001	0.002
Ga	< 0.002	0.011
Pb	< 0.003	< 0.003
Sn	< 0.003	< 0.003
Ca	< 0.001	< 0.001
Zr	< 0.001	< 0.001
B	< 0.001	< 0.001

*by difference

* Presented at a corrosion symposium held in Ottawa, Canada, August 31-September 2, 1953 by the National Research Council of Canada, Associate Committee on Corrosion Research and Prevention. Submitted for publication December 30, 1953.

* Aluminum Laboratories, Ltd., Kingston, Ont.

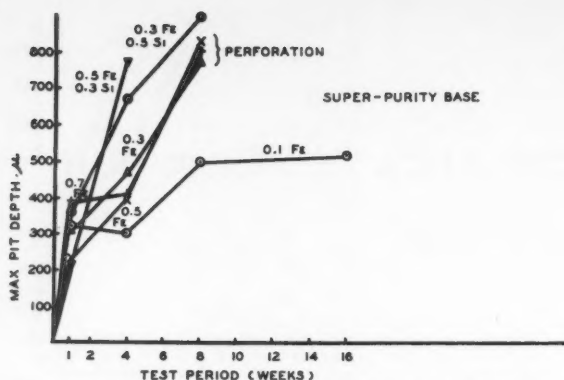


Figure 1—Influence on the rate of pitting of iron additions to super purity aluminum.

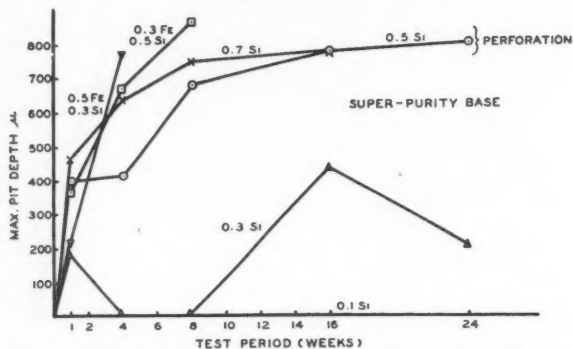


Figure 2—Influence on the rate of pitting of silicon additions to super purity aluminum.

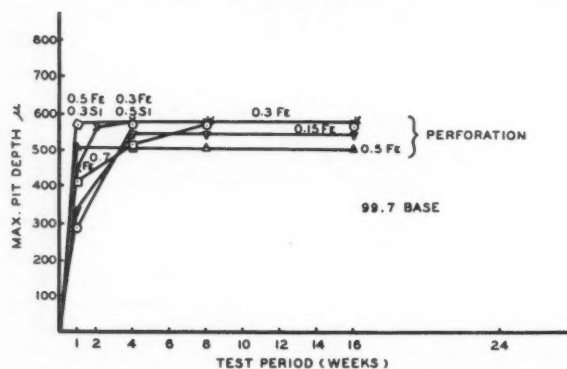


Figure 3—Influence on the rate of pitting of iron additions to commercial purity aluminum.

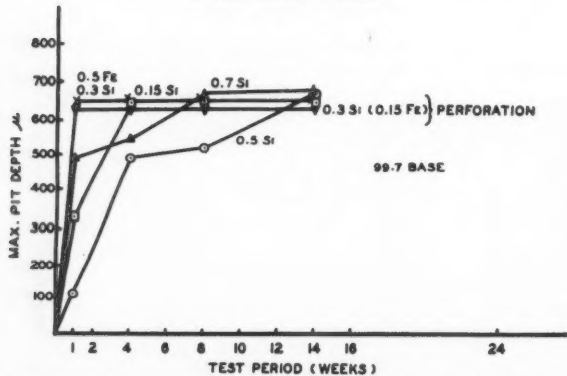


Figure 4—Influence on the rate of pitting of silicon additions to commercial purity aluminum.

TABLE 2
Composition of Commercial Purity Aluminum
With Iron Silicon Additions

COMPOSITION SOUGHT		COMPOSITION OBTAINED		
Percent Fe	Percent Si	Percent Fe	Percent Si	Percent Cu
0.15	0.10	0.14	0.10	0.003
0.15	0.20	0.14	0.23	0.004
0.15	0.30	0.15	0.32	0.004
0.15	0.50	0.16	0.50	0.005
0.15	0.70	0.14	0.66	0.005
*0.20	0.10	0.18	0.10	0.004
0.20	0.20	0.20	0.21	0.005
*0.20	0.30	0.18	0.28	0.005
*0.20	0.50	0.20	0.48	0.006
*0.20	0.70	0.18	0.71	0.005
*0.30	0.10	0.30	0.10	0.004
0.30	0.20	0.27	0.22	0.006
0.30	0.30	0.28	0.30	0.004
*0.30	0.50	0.30	0.50	0.006
0.30	0.70	0.28	0.65	0.004
*0.50	0.10	0.52	0.10	0.005
0.50	0.20	0.47	0.20	0.005
*0.50	0.30	0.48	0.30	0.004
0.50	0.50	0.45	0.48	0.004
0.50	0.70	0.49	0.64	0.004
*0.70	0.10	0.70	0.10	0.004
0.70	0.12	0.70	0.19	0.004
0.70	0.12	0.69	0.35	0.006
0.70	0.12	0.71	0.49	0.005
0.70	0.12	0.72	0.64	0.004

* Pitting probabilities determined for all alloys. Pitting rates measured for starred compositions only.

TABLE 3
Composition of the Super Purity Aluminum
With Iron Silicon Additions

COMPOSITION SOUGHT		COMPOSITION OBTAINED		
Percent Fe	Percent Si	Percent Fe	Percent Si	Percent Cu
*	0.05	0.003	0.001	0.002
*	0.10	0.003	0.042	0.002
*	0.30	0.003	0.10	0.003
*	0.50	0.003	0.32	0.003
*	0.70	0.003	0.52	0.002
0.05	0.05	0.05	0.001	0.002
0.05	0.10	0.05	0.04	0.002
0.05	0.30	0.05	0.11	0.002
0.05	0.50	0.04	0.29	0.002
0.05	0.70	0.04	0.51	0.002
0.05	0.70	0.04	0.72	0.002
*0.10	0.05	0.12	0.001	0.002
0.10	0.10	0.12	0.04	0.002
0.10	0.30	0.12	0.09	0.002
0.10	0.50	0.10	0.29	0.002
0.10	0.70	0.11	0.52	0.001
0.10	0.70	0.12	0.72	0.001
*0.30	0.05	0.34	0.001	0.002
0.30	0.10	0.33	0.04	0.002
0.30	0.30	0.32	0.08	0.002
0.30	0.50	0.34	0.27	0.002
*0.30	0.70	0.34	0.49	0.001
0.30	0.70	0.34	0.71	0.001
*0.50	0.05	0.49	0.002	0.002
0.50	0.10	0.50	0.04	0.002
0.50	0.30	0.52	0.09	0.002
*0.50	0.50	0.52	0.27	0.002
0.50	0.70	0.56	0.50	0.001
0.50	0.70	0.56	0.69	0.002
*0.70	0.05	0.74	0.002	0.002
0.70	0.10	0.74	0.04	0.003
0.70	0.30	0.72	0.09	0.002
0.70	0.50	0.77	0.28	0.002
0.70	0.70	0.80	0.46	0.001
0.70	0.70	0.78	0.70	0.002

* Pitting probabilities determined for all alloys. Pitting rates measured for starred compositions only.

TABLE 4
Composition of Kingston Tap Water²
(pH 8.0)

	PPM
Residue on Evaporation.....	161
Total hardness.....	127
Bicarbonate as HCO ₃	114
Sulphates as SO ₄	22
Chlorides as Cl.....	30
Calcium.....	57
Magnesium.....	8
Silica.....	4
Iron.....	0.05
Copper.....	0.015
Electrical Resistivity.....	270 recip. megohms at 20°C.

into 1/2-inch squares with a 10 percent solution of paraffin wax in carbon tetrachloride. The ruling was carried out with an ordinary draftsman's lining pen. A controlled volume of Kingston tap water (2 ml) was delivered onto each square with a syringe and the panels were then placed over water in a closed container to prevent evaporation. After exposure for seven days the panels were removed, washed and dried and the number of pits per square counted and recorded. Three panels of each of the commercial purity alloys and four panels of each of the high purity alloys were exposed. The composition of Kingston tap water is given in Table 4.

The pitting probabilities P were computed from the formula

$$P = \frac{N_p}{N} \times 100 = \text{Probability}$$

where N = the total number of squares exposed.

N_p = the number on which one or more pits develop.

TABLE 5
Pitting Probabilities of Super Purity Alloys

PERCENT IRON	PERCENT SILICON					
	0.001	0.05	0.1	0.3	0.5	0.7
0.003.....	0	0	0	20	14	23
0.05.....	10	15	7	25	12	32
0.1.....	19	4	12	16	18	15
0.3.....	14	21	18	38	39	29
0.5.....	20	23	31	35	28	27
0.7.....	38	13	23	28	20	26

TABLE 6
Pitting Probabilities of Commercial Purity Alloys

PERCENT IRON	PERCENT SILICON				
	0.1	0.2	0.3	0.5	0.7
0.15.....	48	80	90	57	48
0.2.....	30	55	49	61	77
0.3.....	52	63	64	62	81
0.5.....	79	48	58	56	93
0.7.....	96	47	52	56	75

TABLE 7—Pitting Rate Data
Average Number and Maximum Depth of Pits (in Microns)
Super Purity Alloys

PERCENT IRON	Percent Si	1 Week		4 Weeks		8 Weeks		16 Weeks		24 Weeks	
		No.	Max. Pits Depth	No.	Max. Pits Depth	No.	Max. Pits Depth	No.	Max. Pits Depth	No.	Max. Pits Depth
0.1.....	0	0	0	0	0	0	0	0	0	0	0
0.3.....	1	320	1	300	5	500	23	520	8	775	.....
0.5.....	1	318	1	470	8	> 775	11	> 775	11	> 825	.....
0.7.....	1	236	3	405	9	> 825	14	> 800	14	> 800	.....
.....	29	396	1	406	15	> 800	0	0	0	0	.....
.....	0	0	0	0	0	0	1	440	1	205	.....
.....	1	184	0	0	0	0	7	780	2	800	.....
.....	3	400	7	410	11	680	9	> 775	9	> 775	.....
.....	14	465	16	640	9	750	20	> 775	20	> 775	.....
0.5.....	0.3	1	210	24	> 775	19	> 775	40	> 875	40	> 875
0.7.....	0.5	5	360	23	670	38	> 875	.....	.....	.....	.....

Commercial Purity Alloys

0.15.....	0.12	5	335	14	> 650	17	> 650	15	> 650	.....	.....
0.20.....	0.12	95	283	31	> 675	27	> 675	28	> 675	.....	.....
0.30.....	0.12	17	603	14	> 625	16	> 625	31	> 625	.....	.....
0.70.....	0.12	16	408	7	608	27	> 675	19	675	.....	.....
0.15.....	0.30	9	> 625	40	625	46	> 625	44	> 625	.....	.....
0.15.....	0.50	0	0	28	495	28	520	24	> 675	.....	.....
0.15.....	0.70	18	495	20	542	28	670	16	> 675	.....	.....
0.50.....	0.30	46	> 650	38	> 650	14	> 650	45	> 650	.....	.....
0.30.....	0.50	28	452	33	670	34	> 675	38	> 675	.....	.....

2. Determination of Pitting Rates

Ten 2 x 5-inch sheet samples were drilled and threaded onto a glass rod using spacers of rubber tubing. This "string" as the sample group is called, was etched for 2 minutes in 85 percent phosphoric acid at 70 degree C and rinsed in cold running water for 5 minutes. While still wet it was transferred to a tank of Kingston tap water for the duration of the test. A number of strings was immersed at one time, one for each of several time periods (viz. 1, 4, 8, 16 and 24 weeks respectively) so that a pitting rate curve could be drawn. After exposure the specimens were removed, cleaned by treatment in cold 50 percent H_3PO_4 , washed in water and dried. They were examined under a low power microscope (7 X), the number of pits per panel counted and the ten deepest pits circled. Then at higher magnification (250 X) the depths of the circled pits were measured by the focusing technique. Using the deepest pit in the string for each time period a pitting rate curve was drawn. Exposures were carried out in the large thermo-statted tank previously described.¹

Pitting rate measurements were only carried out for the starred alloys of Tables 2 and 3 and for the 2S and 3S controls of Table 4.

Experimental Results

Experimental results of the pitting probability measurements are presented in Tables 5 and 6. Variables employed are the nominal iron and silicon content of the alloys tested. Significance of the boxed areas will be discussed later.

Numerical results of the pitting rate measurements are given in Table 7 and the results are presented graphically in Figures 1-4 inclusive.

Discussion and Conclusions*

1. Pitting Probability Measurements

A statistical analysis of the results presented in Tables 5 and 6 was carried out and the following conclusions drawn:

a. **Super Purity Alloys.** The effect on the pitting probability of additions of both iron and silicon to super purity aluminum is highly significant. There is no significant difference between the probabilities obtained at successive levels of iron. That is to say there is no statistical significance in the change in pitting probability in going from one level of iron to the next succeeding level. This is also true for silicon in excess of 0.3 percent. Below this silicon has no influence.

b. **Commercial Purity Alloys.** No significant increase in pitting prob-

* Although results obtained were in Kingston tap water the conclusions are believed to be applicable generally.

ability could be attributed to additions of either iron and silicon or both.

c. Influence of Base Metal Purity. It is interesting to compare the results obtained on a number of alloys of equal iron and silicon content but with different base purity. Comparison between the outlined boxes of values of the pitting probabilities in Tables 5 and 6 shows that the difference between corresponding pitting probabilities is highly significant. Application of the "t" test showed that the difference has a most probable value of $41 \pm 4\%$ at 95% confidence limits. That is to say, if a series of test results are taken at random from the infinite population of results for the two series of alloys, then 95% of the means of these samples will differ by $41\% \pm 4\%$.

It is difficult to assess such results quantitatively but it appears that the use of commercial purity base metal increases the probability of pitting by a factor of 2.5.

From Table 1 it is evident that appreciably greater amounts of Ga, V, Ti, Mn and Cu (in order of largest amount) were present in lower base purity alloys. Among these, copper is known to have a pronounced effect and may have accounted for the difference. Mn would not be expected to have any effect nor would V and Ti although this latter may be an unwarranted assumption. There is no published information available upon the influence of Ga. It is hoped that further work in progress will reveal the cause of the difference.

It is interesting to note that the addition of silicon up to a level of 0.1 percent has not changed the pitting probability of super purity aluminum, whereas the addition of 0.3 percent increased it from 0 to 20. The addition of even 0.05 percent iron increased the pitting probability from 0 to 10.

In the study of aluminum-manganese-magnesium alloys,¹ it was found that there was no significant difference between the pitting probability of 99.5

percent aluminum and 99.7 percent aluminum or their corresponding alloys. This is also borne out in the present investigation since adding iron and silicon to the 99.75 percent metal in amounts up to 0.7 percent had no significant effect on its pitting probability.

2. Pitting Rate Measurements

a) The results show that both iron and silicon accelerate the rate of pitting of aluminum. The addition of 0.1 percent iron to super purity aluminum causes severe pitting while further additions tend to have very much less effect on the pitting rate but do cause a larger number of pits. Thus the addition of 0.3 to 0.7 percent iron to super purity aluminum increases the pitting rate only very slightly over that caused by the addition of 0.1 percent. For silicon it is necessary to add at least 0.3 percent to super purity in order to initiate marked pitting. The addition of 0.5 percent has a much larger influence but above 0.5 percent there is little effect.

b) The iron and silicon in the commercial purity base metal is so high initially that further additions do not alter the pitting rate appreciably. Also the overriding influence of iron and silicon in commercial purity metal makes it impossible to notice the influence of minor alloying contaminants which would also be present.

c) A study of the average number of pits per panel confirms the conclusion drawn in the probability work that no differences existed in the pitting probability of the commercial purity alloys at different levels of iron and silicon.

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Relation of Corrosion to Business Costs*

By AARON WACHTER*

EVERY COMMERCIAL and industrial enterprise desires to achieve optimum gains. This is commonly put more bluntly by the business man's statement, "we are in business to make money." It seems reasonable that the businessman with this as his aim will recognize that drains and losses of income detract from his objective. It might be expected that he would have a keen interest in bringing to light and in exercising control over hidden factors responsible for income losses.

This is an attempt to analyze, in a reasonably comprehensive manner, the different ways in which corrosion can and too often does contribute to the cost of business operations involving the use or production of metallic equipment or structures. Every such business, to some degree, suffers losses due to corrosion. These losses appear ultimately in the unit cost of operation or production, in sales losses, or in both. They represent, therefore, drains on profits and factors adverse to the competitive position of a company.

In indirect as well as direct ways, everyone and

Abstract

Every business can benefit from reduction of its losses due to corrosion. Awareness of all possible sources of such losses is essential. Unnecessary acceptance of losses is common from chronic corrosion which is tolerated as established custom, and from hidden or indirect effects of corrosion. The importance of corrosion damage is not always proportional to the volume of metal affected.

The functional aspects of corrosion are listed. Analysis is made of the ways in which corrosion enters into the cost of doing business. Explanations are given of the direct and indirect ways corrosion may effect capital investment, operating costs, product sales, maintenance costs, overhead costs and market competitive condition of and company.

every business pays for the cost of corrosion. Underground corrosion is costing American industry in the order of \$1 billion annually.¹ Its adverse effects are suffered by most operators of underground plant and to an extent by their customers and the general public. The structures affected are 1,092,000 miles of water, gas and oil pipe lines, 418,000 miles of railroads, 211,000 miles of metal-sheathed cables buried directly in the ground or placed in conduit, also innumerable tanks, and foundations.

Probably everyone is aware that the total annual cost of corrosion in the United States is estimated at \$5 to \$6 billion.² This loss has to be included in the cost of goods and services or paid for by taxes. Pri-

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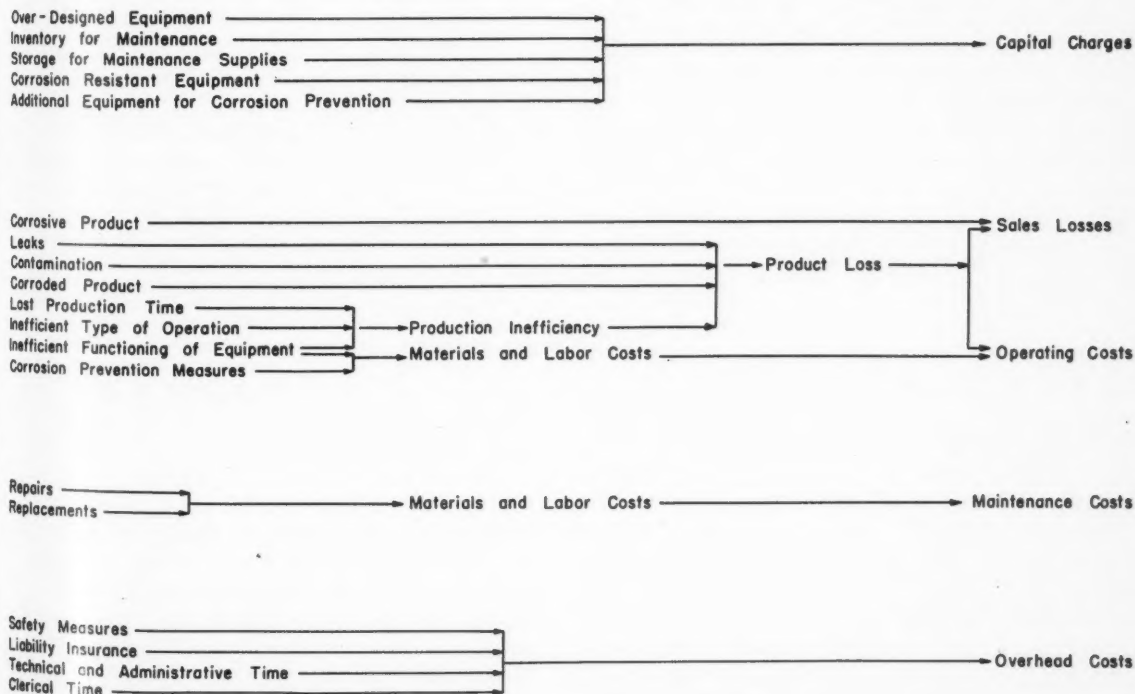


Figure 1—Relation of corrosion to business costs.

vate individuals all pay for this loss even though it is not itemized on the price tag or bill. This amounts as an average to about \$35 per year for every person in the country, but is sufficiently hidden so that rarely is one conscious of it. The only way this huge toll may be reduced is at its various origins. The difficulty is that many businesses may not appreciate all the different ways that corrosion is costing them money in their own operations.

There are extreme examples of this lack of awareness. The authentic story is told of an oil field production foreman who, when asked if he had any corrosion problems, firmly replied "No." Of course, he had problems in his oil field, but corrosion certainly was not one of them. This was said while standing within sight of a scrap pile of corroded equipment covering several acres. When asked how he could make such a statement in the face of that large scrap pile, he explained that it was all worn out equipment, and there was no problem in getting replacements. As long as his storehouse was well-stocked with replacement parts, he had no corrosion problem.

Then, there is the story of a corrosion engineer in the Northwest who visited a large farm in the course of a survey of corrosion problems in agriculture. The farmer told him that he had no such problems, no trouble at all from corrosion. While walking around the group of farm buildings the engineer noticed a truck loaded with several lengths of large pipe and an electric welding machine. This he learned was in fairly steady use to repair leaks and replace sections in the network of steel irrigation lines that traversed the farm.

Acute unusual troubles caused by corrosion are readily appreciated, and steps are taken to ameliorate them, at least to the point where operations can proceed. Chronic customary corrosion tends to be accepted as natural; familiarity causes it to be tolerated.

When equipment fails it is not always readily apparent that corrosion may be the primary and key cause. Corrosion manifests itself in many different forms, all of which are not easily detected or recognized. Some of these forms are intergranular corrosion of stainless steels, dezincification of brass and graphitization of cast iron. Corrosion and mechanical factors cooperate to accelerate deterioration which would be mild in the absence of either. For example, combination of mild corrosion with cyclic stressing may lead to premature breakage called corrosion fatigue, static stresses plus corrosion may cause penetrating fine cracks and movement between mating metal surfaces when combined with slight corrosion may result in rapid corrosive wear.

Corrosion makes its appearance in a great variety of forms and to varying degrees. It is inadequate to view it as a destructive phenomenon that only leads to holes in metal when unchecked. Gross amounts of metal wastage are not always involved in serious corrosion problems. For example, the loss of only 1/4-pound of metal from various functionally critical places of an automobile weighing over 3000 pounds

means the difference between a fine new car and a junk yard resident.

Here is an example of another type. Steel structures exposed to weather often are painted primarily to obtain a good appearance. This is necessary because rusted steel is unsightly, dirty and causes unpleasant staining of adjacent construction materials. It is necessary to apply a protective paint coating because corrosion impairs appearance. A large proportion of the effort that goes into development of improved paints is concerned with means for delaying the onset and spread of corrosion at the steel-paint film interface.

Not only is it difficult sometimes to recognize that corrosion is responsible for deterioration of equipment, but also the business management and the operating executives and engineers in a company may not be conscious of the indirect and less-obvious ways by which corrosion affects the cost of conducting the operations of their enterprise. Before focusing attention on these, it may be helpful to analyze what makes corrosion a practical and therefore a money-wasting problem. What is a corrosion problem? This can be answered if we consider the main types of functions that metals may be required to perform.

Functional Aspects of Corrosion

Corrosion becomes a practical problem when it affects the functions of fabricated metals, of metallic equipment, structures or products.

What are the basic functions of metals when fabricated into various articles or equipment or structures?

1. **Impermeability.** Ability to function as a container. E.g., tanks, pipes, food cans, chemical process equipment.
2. **Mechanical Strength.** Ability to sustain stresses imposed by service. E.g., pressure vessels, structural elements of equipment, springs, pump shafts.
3. **Dimensional Stability.** Maintenance of dimensions or surface finish required for efficient operation. E.g., pistons, valves, razor blades, gasoline pipe lines, electrical contacts, mirrors.
4. **Physical Properties.** Maintenance of special physical properties required for efficient operation. E.g., heat exchangers, electrical equipment.
5. **Contamination.** Ability to avoid contributing metal corrosion products to materials that come into contact with the metal. E.g., equipment for processing and containing foods and pure chemicals.
6. **Appearance.** Ability to retain acceptable surface finish. E.g., ornamental or architectural metal work, household articles, cutlery.

With these functional aspects in mind then a business-like search may be made for all the various ways that corrosion may add to costs in a business.

The cost of production or manufacturing is the sum of four main types of cost. These are: interest and depreciation charges on the capital investment; the costs of conducting the operations of production which include costs of labor, materials and product losses; the costs of corrective and preventive maintenance which are made up of labor and material costs; and finally, the overhead costs which include miscellaneous items not covered by the three classes mentioned. The effect of corrosion on the costs of

each of these items is described in the following paragraphs and illustrated in Figure 1.

1. Capital Investment

Following are the various ways that corrosion may increase the capital investment required in a business.

Greater Initial Capital Investment to Provide Corrosion Resistant Equipment

If it is known that production equipment will suffer from corrosion, the equipment may have to be constructed of resistant and more costly engineering materials, or have appropriate protective coatings or linings applied. Although such costs may be very large they may be unavoidable. Chemical processes are especially likely to require special alloy equipment. If stainless steels or stainless clad steel is required for a process, capital costs for many types of equipment will be considerably higher than if carbon steel could be used. The general average for an entire chemical plant of stainless is likely to be about twice its cost in carbon steel.

The decision to use alloy equipment should, of course, be based on knowledge that this would be less costly in the long run than use of cheaper, less resistant metals or than use of other means of corrosion prevention.

There is no doubt that many perfectly sound and otherwise economically attractive chemical processes are known for which excessive capital outlay would be needed to provide suitably corrosion resistant equipment. As a consequence, these plants are not built and the industrial advantages of a new or better or cheaper product are lost. These situations are attractive opportunities for corrosion research and the corrosion engineer.

Over-Design of Equipment Due to Corrosion

Another way that costs ascribable to corrosion may increase capital investment is by over-design of equipment to allow for possible corrosion. There is no doubt that significant sums of money often are spent to provide greater than the minimum thickness of metal required for adequate strength in order to insure continued performance despite metal wastage by corrosion. More metal than necessary may be specified when corrosion is expected but the actual rates of corrosion are not known. In any event, if corrosion did not occur or could be prevented, the factor of safety used in design might be much smaller.

Over-design is common for reaction vessels, pipe lines, storage tanks, oil well sucker rods and most marine structures. It is common practice to over-design heat exchangers by providing more heat exchange surface than would be required if corrosion product scale, which reduces heat transfer, could be prevented.

The magnitude of this factor can be appreciated by reviewing the design of pipe lines carrying natural gas and petroleum. Pipe lines laid without protection are provided with walls exceeding the thickness required for operating pressures. The thicker wall is for the purpose of avoiding early perforation by cor-

rosion from the outside. With adequate external protection the wall thickness can be reduced 20 to 35 percent and still allow an ample safety factor with regard to internal pressures. For example, 225 miles of 8-inch pipe reduced in wall thickness from 0.322 to 0.25-inch saves 3700 tons of steel³ valued at about \$500,000 at this time.

The reduction of wall thickness incidentally provides a pipe of larger internal diameter having approximately 5 percent greater capacity, which is a gain additional to the initial saving of steel.

Another variety of over-design which increases capital costs is the specification of more costly alloys or special materials of construction than actually are required to resist corrosion adequately. Money is needlessly spent if an 18-8 stainless steel is provided when a 5 chromium steel would do the job, or when protective coatings and cathodic protection are applied to underground pipe lines in regions where no corrosion of bare steel would occur. In such instances it would be more accurate to refer to the "factor" used in design as an ignorance factor rather than as a safety factor. This may not be the engineer's fault. Too often the basic information or data simply are not available. Further research and testing are needed to make possible more precise and reliable engineering.

Inventory of Repair Materials and Replacements Required Because of Corrosion

Maintenance costs due to corrosion will be discussed separately, but at this point attention is directed to the increased capital investment in replacement equipment, spare parts, or special repair materials that may be required owing to corrosion. A large plant may have a considerable investment tied up for such purposes because otherwise the delay in obtaining replacements or corrective materials would stop production for an intolerably long time. Management may point with pride to well-stocked store-rooms prepared to cope with most plant equipment failures. The question that should be asked is how much would be stocked if there were no corrosion in the plant?

In chemical or petroleum or similar process plants, costly items such as spare heat exchanger tube bundles, pumps and pump impellers, valves and even spare reactors are stocked. Not only replacement equipment and parts, but also an inventory often must be kept of repair materials such as welding rods and welding machines, alloy plates, metalizing or coating equipment and machines.

Additional storage facilities have to be provided for all this equipment and materials and the accounting office has to keep track of it all. Thus, to some degree, it contributes to overhead costs.

All these may be readily justifiable as good business in view of the known corrosion experiences of the plant but nevertheless are part of the toll taken by corrosion from a business.

Cost of Additional Equipment Used for Corrosion Prevention

In order to combat corrosion in the most effective

and economic way, it may be necessary to install special additional equipment. Thus, an additional capital expenditure would be involved but the net result may be reduction of maintenance or of operating costs which more than offset the capital charges. Again, this can be good business but may represent a significant although reduced charge due to corrosion.

Types of equipment that come under this heading are pumps, storage tanks and auxiliary equipment for feeding corrosion inhibiting chemicals or neutralizing agents; cathodic protection rectifiers and facilities; dehumidifying equipment used in "moth-balling" ships or to reduce internal corrosion in gasoline tankers; and process equipment (deaerators, fractionators, separators, washers, etc.) to remove corrosive contaminants from process fluids. Some of these can be rather costly; dehumidifying equipment for a tanker may cost well over \$50,000.

2. Operating Costs

Following are the various ways corrosion can contribute to operating costs.

Production Time Lost Due to Corrosion

When equipment fails owing to corrosion, production of salable product or service stops. If this stoppage is prolonged, severe economic penalties may result. This would be likely in a highly competitive business or when ready markets exist for the full production capacity of the plant. In the former case, inability to meet commitments may result in loss of business to competitors; in the latter case, the loss of profits may be irretrievable. Management often calls such losses intangible. This simply means that it is difficult to estimate the dollar cost, although the loss may be very real and large.

In a chemical plant, the "stream efficiency" may drop 5 percent (say from 95 down to 90 percent) owing to interruptions caused by corrosion, without arousing serious alarm. Much more may bring the operation dangerously close to the break-even mark.

Decreased Rate of Production Due to Corrosion

By affecting the efficiency of equipment, corrosion can create bottlenecks in operations or production and thus prevent realization of profits that otherwise would be obtained, as well as possibly increasing direct operating costs.

Corrosion is one of the major causes of inefficiency in heat exchange equipment such as condensers, coolers and heaters, because adhering scale on the metal surfaces due to corrosion markedly reduces over-all heat transfer. This in turn may reduce throughput of the plant and increase fuel and water costs. Steam generating boilers are in this category. It has been mentioned already, in connection with capital costs, that such experience is so common that it is fairly standard procedure to over-design heat exchange equipment (by as much as 25 to 50 percent) in anticipation of efficiency losses.

Another operation where corrosion affects efficiency is in pipe lines. Internal rusting of gasoline lines causes roughening of the pipe surface, which seriously increases the flow friction and thus reduces pipe line throughput capacity. Prevention of this internal corrosion by use of an appropriate corrosion inhibitor raises such capacity by about 15 percent.

Another operation in which efficiency is adversely affected by corrosion involves transportation of petroleum products in tank ships. The heavy rust scale that forms on the walls of cargo compartments acts as a sponge, retaining previous contents, and thus necessitates drastic washing to gas-free these holds and to prevent contamination of subsequent different products.

Process Improvement Impeded by Corrosion

In some instances corrosion may be penalizing a business, also in an intangible way, by compelling it to forego a more economic operation than the one in use, simply because the more progressive method is saddled with some intolerable aspect of corrosion. In other words, if corrosion did not enter, another process would be more advantageous with respect to efficiency or in giving a better, more competitive product. Thus, corrosion may obstruct industrial progress. There are many examples of such progress made possible by overcoming corrosion.

Not many years ago, a gasoline pipe line would have required tanks at all terminals and take-off points and would have relied on tank gauging for volume measurements of gasoline received and delivered. Lines transporting many different finished petroleum products would need a very large number of such tanks. Now, precision line meters provide efficient, less costly means of measurement in place of tank gauging. This development was made possible by the success of corrosion inhibitors in preventing internal rusting of these pipe lines because, without good corrosion control, the rust suspended in the swiftly flowing stream would caused rapid wear and intolerable inaccuracy of the meters.

Another example is the recent accomplishment of synthetic production of ethyl alcohol from petroleum by direct hydration of ethylene, which became feasible only after the inherent severe corrosion problem was brought under control.

Leaks and Spills Due to Corrosion

Losses of process materials which result from leaks and spills caused by corrosion failures of equipment usually are obvious and often negligibly small. Sometimes, though, they are completely overlooked and occasionally can be very large.

In production of crude oil and natural gas, leaks due to corrosion of well casing (internal or external corrosion) may go undetected for long periods. Oil may leak steadily through a small hole in casing into a lower pressure formation above the producing formation for several years before detection. This oil cannot be recovered and its value is lost forever.

Corrosion failure of wellhead equipment of high

pressure oil wells can be very costly in terms of fluid loss. A small perforation or crack caused by corrosion is rapidly enlarged by erosive fluid flow, and wide-open flow may result. This is difficult and takes time to bring under control, especially if a fire ensues. Sometimes complete loss of the oil well follows.

Contamination Due to Corrosion

In some cases only trivial metal loss by corrosion of equipment can cause important losses. Contamination of end products with small amounts of metallic compounds may cause market rejection of such products and the necessity to reprocess for purification or, if purification cannot be accomplished, the product may have to be downgraded and sold at a loss, or perhaps even disposed of as waste. This aspect is especially important in the food, drug, cosmetic and chemical industries. Metallic contamination may give objectionable taste, color, or appearance to a product, or even adversely affect some use function of the material. When a competitor in the same business is able to prevent corrosion and avoid objectionable contamination, he gains a marked business advantage.

The problem of avoiding contamination by corrosion is significant not only in the process equipment of the plant but also in containers for shipping and storing the products. The canned food industry is especially conscious of this problem.

In special cases metallic contamination may result in product loss in a different manner. This may be found in chemical processes where such contamination poisons a desired reaction, or catalyzes an undesirable reaction. A very costly instance of the last was encountered some time ago in a chemical plant where the metal salt formed by slight corrosion of a nickel-lined fractionating column catalyzed a chemical reaction giving many tons each day of an unwanted and unsalable product. This was finally brought under control by use of an appropriate corrosion inhibitor.

Unsalable Product Due to Corrosion

At this point attention can be focused on the out-of-pocket and the potential-profit losses caused by the effects of corrosion on product sales.

When the manufactured product is a metallic article or has metallic components, it seems clear that the sales appeal of the product will drop if the product should suffer visible corrosion during shipment, or storage, or display, or in subsequent end use. Sales advantage and a stronger competitive position go to the business whose product does not suffer from such objectionable effects. Sales promotion of aluminum nails for the exterior of houses is a recent example of this.

Sales advantage also accrues to companies marketing non-metallic products if these products do not cause corrosion of their shipping and storage containers, or of end-use equipment. These are current problems with insecticides and biocides for agricultural uses, with some fire extinguishing fluids, with industrial vapor-degreasing fluids, with some detergents and cleaning compounds, with germicides for

surgical instruments and with machine cutting oils, to mention only a few.

Operation of Corrosion Preventive Measures

When use of a corrosion preventive method involves an additional simultaneous operation which has its own materials, labor and service charges, such costs are properly added to production operating costs even though the operation prevents corrosion which would be much more costly. Examples of such costs are: the costs of corrosion inhibiting or neutralizing chemicals, and power and labor costs for feeding and controlling dosage of such chemicals; costs associated with use of cathodic protection; operating costs for special units (e.g., deaeration, dehumidification, absorption, fractionation, separation) that are used primarily to reduce corrosion.

3. Maintenance

An important source of production costs are those involved in corrective and protective maintenance of equipment. The part that corrosion plays in increasing such costs usually is more readily recognized and appreciated, because these are fairly direct, accountable, out-of-pocket costs.

The total maintenance materials and labor costs attributable to corrosion can be derived from repair costs expended to correct corrosion damage or to prevent it, and from equipment replacement costs due to corrosion. Since most everyone is reasonably conscious of these costs, it is unnecessary to expound at length on this phase of the subject. It might be interesting, however, to mention a few examples.

Ocean-going gasoline tankers are very costly items of equipment that suffer from rather severe internal rusting. Periodically this corrosion advances to the stage when extensive repairs must be made. It is reported⁴ that a 12,000 ton tanker after about 7 years' service was out of commission for 6 months (note that this means loss of income) while bulkheads were renewed at a total cost of about \$500,000, which amounts to more than \$70,000 per year of service. Corrosion preventive methods are now becoming available for substantially reducing such costs.

It is well-known that corrosion, if unchecked, can be the cause of very large maintenance costs on underground pipe lines. One oil company reported⁵ that corrosion was costing \$1,500,000 per year on a large pipe line system prior to installation of protective magnesium anodes. It is expected that most of this large expenditure will be avoided now.

Another report describes net savings of \$14,200 per year realized at the steam plant of an aircraft manufacturer as the result of corrosion preventive program involving treatment with an inhibitor plus slight mechanical revisions.

Another report⁶ from a refinery cites reduction of maintenance costs for heat exchangers resulting from corrosion control measures. Annual maintenance charges were reduced from \$1.20 per square foot of heat exchange surface to \$0.45 per square foot and

distinctly improved operation of the plant resulted as well.

Another refinery reported net savings of over \$24,000 per year from reduction of maintenance costs on a 10,000 barrel tube still by corrosion control methods.

In one refinery, replacement of Admiralty brass tubes with steel tubes in water-cooled heat exchangers, accompanied by treatment of the water to make the steel last about 4 years, is expected to give maintenance savings of about \$30,000 per year.

Many other examples could be cited.

4. Overhead Costs

Finally, in this systematic scrutiny of the different ways corrosion contributes to business costs, there are several different items which, in a business-like manner can be listed under the catch-all heading of **overhead**.

Because of corrosion, extra and special safety measures may be required, including safeguards of detection, alarm, personnel protection and emergency disposal equipment. Also, extra inspectors and their equipment may be required owing to corrosion.

Another subdivision under **safety** covers costs of personnel and public damages from accidents caused by corrosion. These costs can be very large at times. A leak caused by corrosion of a gasoline pipe line in a heavily populated area may result in a damaging fire and require large indemnities.

Under **overhead office costs** could be included the technical manpower, the time of engineers and technologists that must be spent in combating damage by corrosion, in overcoming undesired effects of corrosion and in applying corrosion preventive methods. Research and testing work on corrosion would give additional related costs.

Some portion of accounting and clerical work

might also be incurred as a result of corrosion. This might be much larger in a business like a domestic water supply company in which corrosion may affect a large number of scattered customers than in a business in which corrosion only affects the economics of a centralized plant.

It is likely that, in making this analysis of the relation of corrosion to business costs, some special ways that corrosion may add to costs inadvertently have been omitted. In general, it can be taken to cover, in a reasonably comprehensive way, the main cost contributions of corrosion.

The question then arises. What can be done to correct these money-wasting situations?

First, is needed awareness by business that the problems exist and are costing them money. Application of measures to reduce or eliminate these costs would naturally follow evaluation of the economics involved in each situation. Then, more fundamental research on corrosion is needed. Corrosion engineering can only grow in effectiveness in savings and in making money as the science of corrosion develops. Scientific facts and principles are basic tools for the corrosion engineer. Just as cures for the ills of man depend on developments from medical research which then are applied by the physician, so cures for the ills of equipment depend on corrosion research developments applied by the corrosion engineer.

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Corrosion of Bronze Oil-Sealing Sleeves In Centrifugal Gas Compressors*

By EDWARD C. GRECO

Introduction

AN INCREASED number of failures of phosphor bronze oil-sealing sleeves in centrifugal compressors has been observed in certain compressor stations of a major pipeline company (not United Gas Pipe Line Company). Failures occurred with greater regularity and frequency when steel wirebrush pipeline scrapers were substituted for the less aggressive rubber-bladed scrapers. These cleaners are run through the lines at regular intervals of time to reduce friction and maintain a high gas flow efficiency. The cleaners are placed in the line at one station and removed by means of a trap at the next station. This practice is followed over the entire system except at certain river crossings where the piping is such as to prevent the running of scrapers. It was observed that stations directly after river crossings had less failures than stations along the pipeline where scrapers were used. The removal of the oil from gas scrubbers aggravated the condition and in stations with ten compressor units failures of oil-sealing sleeves reached a frequency of one every five to seven days.

The centrifugal compressor is equipped with an inner and outer phosphor bronze shaft oil-sealing sleeve. Where the shaft passes through the blower a seal is provided to prevent leakage of high pressure gas from the compressor casing. The seal consists of a polished steel collar with stellited faces mounted on the shaft and revolving between two stationary bronze sealing sleeves. The sleeves are free to slide axially and are held in contact with the collar by springs and oil pressure. Oil from the system provides lubrication and cooling. The bronzes are essentially solid solutions of tin and copper. Copper tin alloys containing more than 8 to 10 percent tin usually are used in the form of castings. These cast bronzes are used as bearings, bushings, gears, etc.

Both the inner and outer shaft oil-sealing sleeves are constructed of a phosphor bronze which meets American Society for Testing Materials Specifications, EA-B 144 Alloy 3Y indicated in Table 1.

TABLE 1—Specification Composition of Oil-Sealing Sleeves

	Percent		Percent
Copper	82.0 - 85.0	Iron	0-0.15
Tin	7.0 - 9.0	Nickel	0-1.00
Lead	7.0 - 9.0	Antimony	0-0.35
Phosphorus	0.05- 0.19	Silica	0-0.003
Zinc	0- 0.75		

The compressor units are equipped with an oil

*A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Tulsa, Okla., Oct. 7-9, 1953.
*These are calculated hypothetical combinations and represent probable compounds present in the oil deposits.

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Abstract

Pipe line dust was suspected as the reason for the frequent failure of phosphor bronze oil-sealing sleeves in centrifugal gas compressors when analyses of oil from the sealing systems showed appreciable quantities of iron sulfide. This was picked up, along with iron oxide and silica, from pipe line dust created by the passage through the line of steel wirebrush scrapers. Corrosion product resulting from the attack by this dust clogged up oil passages and caused failure of the sleeves.

Laboratory tests with oil from the seal oil system were made with copper strips. These tests indicated the dusts picked up by the oils were responsible for the corrosion.

Tests with both seal oil and scrubber oils on mild steel, aluminum, Monel, Inconel and nickel showed these suffered no attack. A cellulose-type filter was substituted for the previously used Fuller's earth filter in the seal oil system and after 7 months' observation was found to be substantially more efficient than the Fuller's earth. Meehanite oil seal rings were substituted for the phosphor bronze sleeves and the failures due to iron sulfides were eliminated.

system which operates at a circulation rate of fifteen gallons per minute. The seal oil functions as a cooling medium, a lubricating medium and to seal the compressed gas within the centrifugal compressor and from the atmosphere. The oil system incorporates an oil filter charged with Fuller's earth to remove foreign particles from the circulating seal oil.

Since a small portion of the main gas stream is in continuous contact with the seal oil, any suspended matter which may happen to be in the pipeline gas comes in contact with and is, in part, picked-up by the seal oil. Through this means fine particles of pipeline dust enter the seal oil system.

Iron sulfide is usually found in pipeline dust in varying amounts. This is true even when the gas in the pipeline contains only extremely small amounts of hydrogen sulfide.

Pipe as received from the mill is covered with mill scale (Fe_3O_4), often termed magnetite. Hydrogen sulfide reacts quite readily with iron oxides and thus the mill scale has a tendency to remove a large

percentage of the hydrogen sulfide from the gas stream. These iron sulfides which are the reaction product of hydrogen sulfide and mill scale, ordinarily have a tendency to accumulate and remain fixed to the pipe wall except where other foreign materials such as silica, for example, move along the pipelines and disturb it by abrasion. This fine black abraded material, a mixture of sand, iron oxide and iron sulfide, is called pipeline dust. Pipeline dust samples analyzed at various times over a period of several years have been found to contain from 0.74 to 10 percent iron sulfide. The composition of a typical pipeline dust as calculated from chemical analyses is shown in Table 2.

TABLE 2—Typical Pipeline Dust

	Percent
Iron Oxide	85
Iron Sulfide	4
Silica	11

Inspections of the oil-sealing sleeves which had failed revealed a heavy black deposit on the face and bearing surface. Copper floats taken from the sealing oil system also were covered with a poorly adherent black scale. Beneath the black scale the oil-sealing sleeves were heavily pitted.

These series of observations strongly suggested that the agents responsible for the failures would probably be found in the seal oil. In order to carry out studies in the laboratory, samples of the seal oil were secured. These samples were taken from the sumps of the seal oil system at Compressor Station A where frequent failures were occurring. A sample of the scrubber oil from Station B was also secured. It was thought that the scrubber oil would contain the same corrosive agents suspected to be present in the seal oil.

Laboratory Studies

In order to approach a solution to the problem it was first necessary to determine the approximate composition of the heavy black corrosion products found on the oil-sealing sleeves. These black scales were analyzed and found to contain 84 percent copper sulfide, 6 to 7 percent lead sulfide, 6 to 7 percent stannous sulfide, 0.2 to 1 percent free sulfur and from 0.2 to 0.4 percent iron sulfide. The black scale adhering to the copper float from the seal-oil system was found to have the following composition: 6 percent iron sulfide, 92 percent copper sulfide, and 0.8 percent free sulfur, and 1.07 percent silica. These results indicate beyond reasonable doubt that here is a type of corrosion which involves a sulfide.

Seal oil samples taken from the sump of the seal oil system were found to contain heavy deposits of

TABLE 3—Deposits in Seal Oil*

	Percent
Iron Sulfide (Fe_2S_3)	9.48
Iron Oxide (Fe_2O_3)	83.00
Silica (SiO_2)	7.52

* These are calculated hypothetical combinations and represent probable compounds present in the oil deposits.

solid inorganic matter. The scrubber oil also contained appreciable quantities of these deposits. The seal oil samples were found to contain from 0.30 to 0.76 percent of this material which from chemical analysis was calculated to have the composition shown in Table 3.

The particles ranged from 0.2 to 300 microns, with about sixty percent between 2 and 17 microns. The deposits in the scrubber oil was found to have the composition shown in Table 4.

TABLE 4—Deposits in Scrubber Oil*

	Percent
Iron Sulfide (Fe_2S_3)	4.85
Iron Oxide (Fe_2O_3)	89.00
Silica (SiO_2)	6.15

As indicated by the above analyses the seal and scrubber oil deposits contain appreciable quantities of iron sulfide, iron oxide and silica which are characteristic of a typical pipeline dust. The deposits found in the oils originated in the pipeline. It is also evident that the existing oil filters were not efficiently removing the solids.

To determine the effect of the solid particles on metals, laboratory weight loss tests were made using copper strips as test coupons. Copper was selected for the test coupons because this metal was readily available in flat stock. Also, copper is used extensively to detect the presence of corrosive sulfur compounds in lubricants and to indicate if an oil will corrode copper or alloy parts in service.¹

The coupons, 0.5 x 1.5 inches, were cut from 0.023-inch thick copper stock. Each piece was mechanically polished and then carefully measured with a caliper and the total surface area computed. The coupons were degreased in carbon tetrachloride, dipped in acetone several times, air-dried, weighed and immediately placed in the oil which had been preheated to 140 degrees F.

Preliminary long term tests were run using the prepared copper coupons, oils bearing pipeline dust from Station A, new seal oil and the scrubber oil from Station B.

The rate curves for these tests are shown in Figure 1. It is evident from the rate curves that the initial

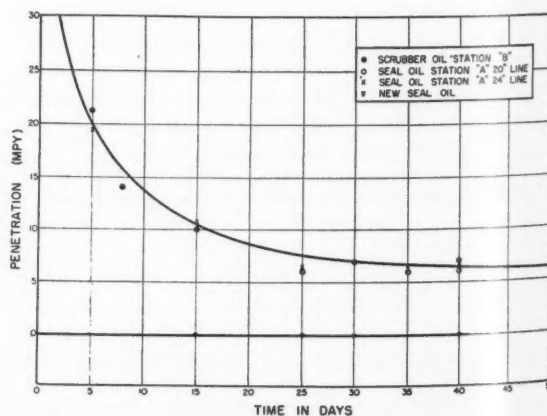


Figure 1—Corrosion rate based on weight loss.

rate of corrosion for both the seal oil and scrubber oil is above 30 mpy. After five days the rate dropped to 11 mpy. A copper sulfide scale similar in appearance to that found on the oil-sealing sleeves was formed on the test pieces. This scale varied from 7 to 24 mils in thickness. The scrubber oil from Station B gave approximately the same corrosion rate as the seal oil from Station A. The new seal oil, after 40 days, showed a zero corrosion rate. Figure 2 is a photomicrograph of the copper test strip after 40 days in the new seal oil. Figure 3 illustrates the copper test strip after 40 days in the seal oil from Station A. Note the deep pitting and non-uniform attack. The entire surface has been attacked and pits of various sizes and depths are visible. Both the seal and the scrubber oils showed the same type corrosion.

Since it has been reasonably established, both by chemical analysis and by corrosion studies, that the scrubber oil contained the same corrosive constituents found in the seal oil, 30 separate corrosion tests were performed employing the scrubber oil from Station B as the corrosive medium. This was done in an attempt to determine the nature of the mechanism responsible for the corrosion of the oil-sealing sleeves.

In re-evaluating the method of preparation, it became evident that some other means must be found to remove all the oxides from the surface of the corrosion test strips and thus secure a more uniform and active surface.

For these tests the copper test strips were prepared as before except for the mechanical polishing. Instead of mechanically polishing, the test strips were degreased in carbon tetrachloride, given a bright-dip in concentrated nitric acid, washed free of acid with water, dipped in acetone several times, air-dried, weighed and immediately placed in the scrubber oil, which had been preheated to 140 degrees F.

Figure 4 represents the graphical results of these tests. In order to estimate the thickness of the scale, the test strips were weighed before and after descaling. Both the as-removed (with scale in place) and the descaled (scale removed) results are plotted. It is to be noted that the shape of the curves in Figures 1 and 4 are similar and that the initial corrosion rate is high. From the weight loss on descaling it is observed that initially the scale weight decreases as corrosion proceeds. At the end of 9 days the corrosion rate dropped to 23 mpy and the scale reduced to 4 mils. This is indicative of a diffusion type reaction where the permeability of the film is the controlling factor.² The corrosion rate is decreasing with time, which indicates a more protective-type surface film. With reference to Figure 1, at the end of thirty days a steady state is reached and the corrosion rate approached a steady value. At this point the scale has possibly become better oriented on the metal surface and, therefore, less porous and more protective. However, the scale does not completely protect the metal because after forty days the corrosion rate still is appreciable. This was also observed by Har- inghauzen and Was³ in their studies of corrosion by



Figure 2—Copper test strip after 40 days in new seal oil—Approx. 6X.

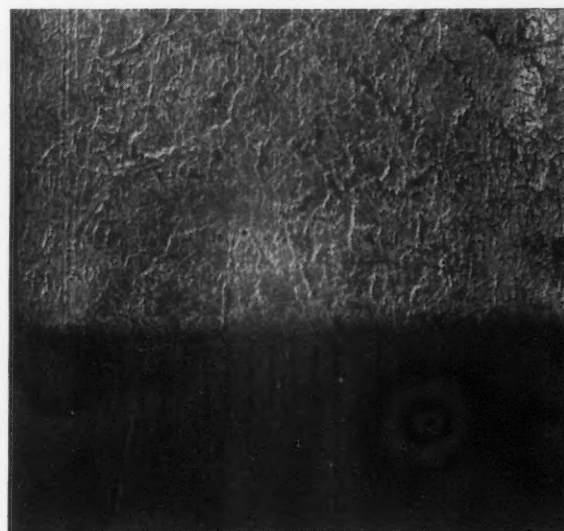


Figure 3—Copper test strip after 40 days in seal oil from Station A—Approx. 6X.

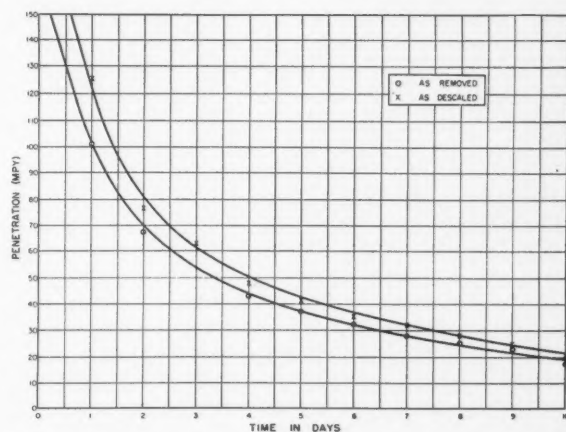


Figure 4—Corrosion rate, based on weight loss, before and after descaling coupons.



Figure 5—Copper test strip after 10 days in seal oil from Station A, 9X.

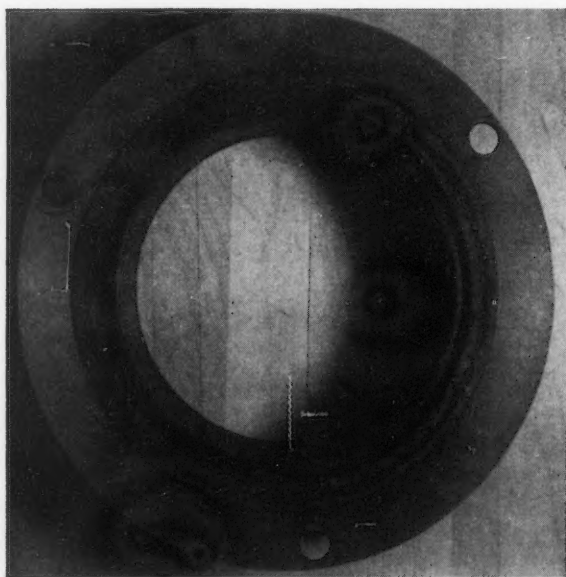


Figure 6—Face and bearing surface of oil-sealing sleeve.

technical insulating oils. They stated that these oils build up a film on the metals, the corrosion-rate being regulated by diffusion through the film, which on some metals (lead and tin) is durable and protective; while on others (copper) the film appears to break down.

Figure 5 shows a copper test strip after 19 days in the seal oil from Station A. The heavy black copper sulfide scale has been removed from the lower section to expose the deeply pitted area. Evidence that pipeline dust in the seal oil is attracted to the oil sealing sleeve is indicated by the analyses of the sulfide scales where varying amounts of iron sulfide were found associated with them. These sulfides were found to be magnetic, indicating the Fe_3S_4 form which is one of the sulfur compounds containing FeS with additional sulfur atoms held "in solution" in its crystal lattice. When corrosion tests were made with mild steel and aluminum test strips in the oils bearing iron sulfides there was very little evidence that iron sulfides were attracted to these metals. The surfaces of the metals remained clean and unaffected throughout the test.

Nevertheless, whatever the exact mechanism involved here, the result is a heavy loose scale which in the main is copper sulfide. The scale continues to build up on the face and bearing surface of the oil-sealing sleeves, Figure 6, until the lubrication ports are plugged. This prevents proper lubrication and cooling, the temperature of the oil-sealing sleeve reaches the critical point and mechanical failure occurs.

Corrosion Studies of Alloys

In the course of the laboratory studies it was thought advisable to determine the effect of oils bearing pipeline dust on other types of metals and alloys. Possibly other metals could be found which are not affected by the iron sulfide and which might be used in place of the phosphor bronze oil sealing sleeves. Five different metals were selected including an aluminum alloy which can be used as a bearing metal. These were tested in the seal oil from Station A as well as the scrubber oil from Station B.

The results of these tests indicated the two oils, seal oil from Station A and scrubber oil from Station B, had very little or no effect on mild steel, aluminum, Monel, Inconel or nickel. There was no tendency for the iron sulfide particles to be attracted to or plate-out on these metals.

The aluminum bearing alloy, Aluminum Company of America Alloy No. 750-T-5, which has been adopted for heavy duty engine bearings, and the mild steel showed excellent resistance to this type of corrosion. After 18 days in the scrubber oil which corroded copper at a rate of 125 mpy, the aluminum and mild steel showed no signs of corrosion. The metals remained clean, retained original surfaces and gave no indications of attracting the iron sulfide particles.

Remedial Measures

Because it was apparent existing Fuller's earth filters did not effectively remove the pipeline dust particles which became entrapped in the seal oil, it was advisable to find a more efficient filter medium. If a more efficient filter medium could be found, the corrosion and subsequent accumulation of scale on the oil-sealing sleeves could be eliminated or mini-

mized. This should result in a sizable reduction of oil-sealing sleeve failures.

In an attempt to find a more efficient filter medium a cellulose type filter material was selected and installed at Station A. The cellulose material used is the type wound on a mandrel. This was preferred to the granular cellulose since the former could be operated at higher flow rates. After installation the efficiency of the filter element was carefully followed by frequent laboratory corrosion studies and analyses of the seal oil.

The cellulose type filter was in service approximately seven months and did an excellent job of removing the foreign particles from the circulating seal oil. During this period, there was no material increase in suspended solids, corrosion rate, or increase in acid number of the seal oil. Before the cellulose type filter was installed, a very heavy, thick, poorly adherent scale formed on the sleeves in a very short period of time. The test strips used in corrosion tests after the cellulose filter had been in service for seven months were found to be partially covered by a thin adherent scale of approximately one-half mil or less in thickness as shown in Figure 7. The film appeared to be much more protective in nature than the films formed while the Fuller's earth filter was in use. The initial corrosion rate had dropped from 125 mpy to 1.2 mpy. It can be stated with a fair degree of assurance that this thin adherent scale will not cause any serious plugging of the lubrication ports of the oil-sealing sleeves nor will the corrosion rate cause any serious damage to them.

Since laboratory corrosion tests showed that the seal oil bearing iron sulfide does not corrode mild steel, a Meehanite metal sealing sleeve was designed to replace the phosphor bronze sleeves. Meehanite is a specially made machinable cast iron in which the molten metal has been treated with calcium silicide. The addition of the graphitizer, calcium silicide, produces a fine graphitic structure, resulting in an alloy which has excellent mechanical properties. The installation of these new type oil-sealing sleeves has eliminated the failures due to iron sulfide corrosion.

Conclusions

Laboratory studies have shown quite conclusively that the frequent failures of the phosphor bronze oil-sealing sleeves are due to iron sulfide particles which have gained entrance into the circulating oil.

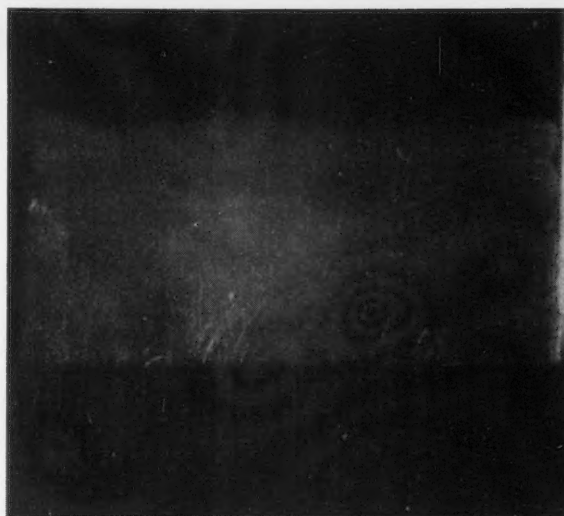


Figure 7—Copper strip test after 19 days in cellulose filtered oil. Approx. 6X.

These solid corrosion products of hydrogen sulfide and iron oxides are attracted to and plate on the copper bearing oil sealing sleeves. The iron sulfides initiate and maintain a high corrosion rate with the formation of a copper sulfide scale which varies from 7 to 24 mils in thickness. The copper sulfide scale plugs the lubrication ports of the sleeves and this subsequently results in their failure.

The cellulose type filters which had been in service approximately seven months did an excellent job of removing a large portion of the foreign particles from the circulating seal oil. With the installation of these filters, laboratory test indicated an 83 percent reduction in the corrosion rate and a 99 percent reduction in the solids content of the oil. The installation of Meehanite metal oil sealing sleeves has eliminated oil sealing sleeve failures.

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Raised Earth Potential*

By ROBERT H. POPE*

DURING the 1920's the principal corrosion problems on underground structures were caused by stray current from grounded d-c trolley systems. The usual protective measure consisted of a "drainage wire" from the structure to the negative bus of the trolley generator. This lowered the potential of the structure below the potential of the earth in the vicinity of the drainage connection and consequently changed an anodic condition to a cathodic condition. This method was practical and effective where the corrosion exposure was reasonably close to the trolley generating station.

Where, due to some unusual condition, a corrosion exposure was created remote from the generating station the drainage method was not practical because the wire required would be too long and too large. G. G. Jones of the Long Lines Department of the American Telephone and Telegraph Company had several such exposures on his cables in Connecticut and Pennsylvania. He reasoned that if the potential of the earth surrounding the cables (as measured with an electrode of cable sheath alloy) could be raised above the potential of the cable sheaths in the exposure area, current would be prevented from leaving the sheaths and the corrosion would be stopped. He figured that the current required for raising the earth potential would be small compared with drainage current values.

The first trial of the raised earth potential (REP) method was made at Southport, Connecticut on October 15, 1919. A steel wire was pulled into a spare duct in the telephone conduit in the exposure area. This was connected by means of an aerial wire to a point on the trolley track which was continuously positive to the cables at the exposure. The method was effective in eliminating the corrosive condition but it had several disadvantages. A rather long aerial wire was required and the fluctuating potential of the duct wire resulted in over-protection and corrosion of the duct wire occurred more rapidly than necessary.

In an effort to eliminate these disadvantages, a local battery was used between the cable sheath and duct wire. In an effort to obtain an inexpensive long life cell, copper and zinc plates were used as electrodes and the water in a flooded manhole was used as the electrolyte. The arrangement and expected results are shown in figure 1, the arrows indicating the protective current. Analysis in light of present experience would indicate that zinc protection was being applied as shown in Figure 2. That this was the principal effect is indicated by the observation that the cell appeared to be more effective when

placed in the manhole with the zinc below the copper. A secondary effect was introduced by the steel-copper couple in which the cable was merely in the current path. This condition is shown in Figure 3. The mild anodic condition caused by the copper remote from the cell location was probably nullified by the action of the zinc (Figure 2) especially when the zinc was installed below the copper in the manhole.

Further experiments were made with REP, including use of a hemp core in the steel stranded duct wire, to insure removal of all of the remaining wire in the duct after the wire had corroded to cause weak spots.

At Paoli, Pennsylvania a corrosion exposure was found even though there were no trolleys nearby. Tests indicated that current from the sheath was directed toward railroad plant which provided conductivity to the generating stations of several trolley lines. Thus, a mild corrosion exposure was created on the cable sheaths even though the trolley lines were several miles away.

With the cooperation of the railroad, a drainage system was installed using a storage battery located in a signal tower. Telephone and railroad cable sheaths were connected to the negative terminal of the battery and the positive terminal was connected to the railroad rails. The battery was kept charged by means of a generator which was operated at regular intervals by the tower attendant. Because the railroad was electrified it was feared that the cables might suffer damage in the event of a short circuit on the railroad near the connection to the rails. Consequently the connection was removed and a low resistance ground substituted for it. This was done on June 23, 1919 and is probably one of the first installations of cathodic protection by the use of sacrificial anodes. But it was still called "Raised Earth Potential." Later, a duct wire was substituted for the ground connection. This system was in operation until March 6, 1936 when it was removed because it was no longer needed.

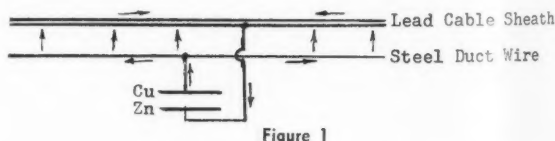


Figure 1

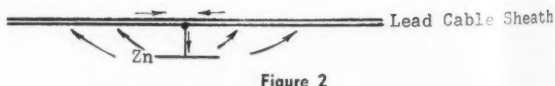


Figure 2



Figure 3

* The third of a series of six articles on early developments in cathodic protection and corrosion mitigation measures on underground structures.

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Radiometric Study of Phosphate Coatings Formed on Steel in Pretreatment Baths*

By THOMAS F. BOYD, MICHAEL GALAN and LEONARD MARKOWITZ

Introduction

IN THE PREPARATION of steel plates for painting which are covered with mill scale, it is good practice to remove the scale by pickling and then wash and dip into a pretreatment bath to provide some degree of rust inhibition. A pretreatment bath is advisable because the plates are very susceptible to rusting after the pickling operation. It is also advisable to apply a primer soon after the pretreatment has dried. A large factor of safety is desirable in the rust-inhibiting properties of the pretreatment bath because, 1) where outdoor operations are necessary, damp or rainy weather may occur before it is possible to paint the steel, 2) the greater the corrosion resistance of the steel before being painted, the greater is the corrosion resistance of the painted surface under actual weathering conditions.

This investigation was conducted to discover whether there was a correlation between the amount of coating formed and corrosion resistance. Radio-phosphorus with radiation of 1.7 Mev, (USAEC Catalogue No. P-32-P-1) was used in the measurement of the very small amounts of phosphate coating.

Experimental Procedure and Results

Mild steel plates (0.09 percent carbon) covered with mill scale were used in this test. The plates were cut into panels, $2\frac{1}{2} \times 3 \times 1/16$ -inch, provided with a $3/16$ -inch diameter hole centered approximately $3/16$ -inch from the $2\frac{1}{2}$ -inch edge. They were cleaned with naphtha and pickled in sulfuric acid, (5 percent by volume, containing .05 percent inhibitor*), at a temperature of 180 degrees F for six minutes. The panels were suspended from glass hooks inserted into the holes. They were washed by dipping successfully into five beakers of water at a temperature of approximately 180 degrees F.

Six sets of panels, consisting of four panels to a set, were then immersed for two minutes in a solution of radio-phosphoric acid (one percent anhydrous, by weight) at temperatures of 84 degrees F (room), 150 degrees F and 200 degrees F. The specific activity of the solution was approximately one microcurie/ml. After drying, the activity of the panels was measured by means of a Nucleonic Geiger tube, type GMWIAAA, with a mica window of approximately 1.2 mg./sq. cm. The pulses from the tube were registered by means of a Berkeley Decade Scaler. The



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Abstract

An investigation has been made of the amount of phosphate coating formed on steel by various rust-inhibiting solutions. The treatments used were phosphoric acid, phosphoric acid with sodium dichromate and sodium nitrite with diammonium phosphate and with sodium phosphates. No correlation was found between the amount of phosphate coating formed and corrosion resistance. The nature of the coating appears to be the significant factor. The most corrosion resistant coatings were formed by diammonium phosphate-sodium nitrite and sodium phosphate-sodium nitrite treatments, the least by phosphoric acid alone.

panels were covered with a brass plate in which a hole $1\frac{3}{8}$ -inch in diameter was cut.

Counts were made for one minute with the sample and plate, inserted in a shelf of a Lucite sample holder inside a $1\frac{1}{2}$ -inch lead shield, so that a circle

* Submitted for publication July 3, 1953. Based on an investigation at the Industrial Test Laboratory, Building No. 121, Philadelphia Naval Shipyard, Naval Base, Philadelphia 12, Pa. The views expressed are the authors' and do not necessarily represent the views of the Department of the Navy.

* Rodine, American Chemical Paint Co., Ambler, Pa.

(1 3/8-inch diameter) on the panel was exposed central to the Geiger Tube window at a distance of 1.7 cm. By this arrangement an identical area on the panel could be measured before and after accelerated weathering tests. After standing overnight, the panels, inclined at an angle of 45 degrees were washed from the top down twenty times with sufficient distilled water delivered from the mouthpiece of a one liter flask, to cover each panel, at 15 minutes intervals. A total of 20 washes was made.

After drying, the panels were rated for corrosion resistance visually, using a numerical scale from 0 to 10 on which 0 represents no corrosion and 10 represents rust all over the panel. The rust on each panel in a set was estimated independently by three observers and the means of the individual observations were averaged for the final rust rating for the set. The activity on the panels was determined as before.

The amount of coating, calculated as anhydrous phosphoric acid, before and after weathering, was determined as follows: A steel panel was cleaned, pickled and washed as described above. A circle 1 3/8-inch in diameter was inscribed in the center, 100 lambdas of the pretreatment solution were placed in

the center by means of a micro pipette and spread as evenly as possibly over the area of the circle. The panel was dried at 105 degrees C and the activity measured. A factor was calculated thusly:

$$\text{One count/minute} = \frac{\text{ounces of coating}}{\text{square foot}} = \frac{\text{weight of phosphoric acid (oz. anhydrous)}}{\text{area of circle in square feet (0.0103) \times \text{counts/minute}}}$$

The weight of the coating on the treated panels was obtained by multiplying the counts/minute for these panels by the factor. It was found from preliminary experiments that over the range of coating expected, no correction for self-absorption was necessary. Therefore the same factor obtained for the 1 percent phosphoric acid pretreatment bath could be used for subsequent pretreatments, after making corrections for radioactive decay and percent of phosphoric acid in the pretreatment bath. All coatings were expressed in terms of anhydrous phosphoric acid to place them on a comparative molecular basis. The tests were repeated with the exception that concentrations of 0.4 percent and 1.4 percent phosphoric acid were used. The test at the 1.0 percent concentration was then repeated varying the temperature and time of immersion. The results are shown in Table 1.

All tests were repeated except that the following percent concentrations (anhydrous basis) of mixtures of sodium dichromate-phosphoric acid, respectively, were used instead of phosphoric acid alone; 0.27, 0.20; 0.67, 0.50; and 0.94, 0.70. The results are shown in Table 2.

Preliminary experiments were made with sodium nitrite-diammonium phosphate pretreatment baths, which indicated good corrosion resistance was obtained at temperatures from room to 200 degrees F and that a coating formed very quickly. Because very good corrosion resistance was obtained at lower temperatures subsequent tests were made only at room temperature and 120 degrees F.

Tests were run at room temperature with an immersion time of one minute, for concentrations of 0.2, 0.5 and 0.7 percent of each reagent. Tests were also made at room temperatures and 120 degrees F with concentrations of 0.5 percent of each reagent and immersion times of 1/2, 1, 2 and 4 minutes. The results are shown in Table 3.

Panels were treated as described above substituting various sodium phosphates for diammonium phosphate. However, washes were made with distilled water in the accelerated weathering test, until rust with a rating of 2 occurred, instead of making 20 washes as previously. Sodium nitrite and diammonium phosphate, each alone, were also included. Pretreatments of phosphoric acid (1.0 percent); sodium

TABLE 1
Coating Thickness and Corrosion Resistance
of Phosphoric Acid Pretreatment

Concentration of Phosphoric Acid (anhydrous) percent	Temperature °F	Time of Immersion Minutes	oz x 10 ⁻² of Coating as Anhydrous Phosphoric Acid (H ₃ PO ₄) per square foot		Corrosion Rating
			Before Accelerated Aging	After Accelerated Aging	
0.4.....	84	2	2.3	2.1	8
1.0.....	84	2	4.3	3.7	9
1.4.....	84	2	6.5	6.4	10
0.4.....	150	2	2.3	2.2	7
1.0.....	150	2	5.0	5.0	7
1.4.....	150	2	6.3	6.4	10
0.4.....	200	2	1.8	2.0	5
1.0.....	200	2	6.9	7.2	4
1.4.....	200	2	9.6	8.9	5
1.0.....	76	2	5.7	5.1	10
1.0.....	76	6	6.3	5.6	10
1.0.....	76	10	5.4	5.0	10
1.0.....	150	2	6.3	5.0	10
1.0.....	150	6	6.2	5.8	9
1.0.....	150	10	6.1	5.8	10
1.0.....	200	2	7.6	6.8	10
1.0.....	200	6	7.6	7.4	6
1.0.....	200	10	8.2	7.7	9

TABLE 2
Coating Thickness and Corrosion Resistance
of Sodium-Dichromate-Phosphoric Acid Pretreatment

Concentration on Anhydrous Basis		Temperature °F	Time of Immersion minutes	oz x 10 ⁻² of Coating as Anhydrous Phosphoric Acid (H ₃ PO ₄) per square foot		Corrosion Rating
Sodium Dichromate (Na ₂ Cr ₂ O ₇) percent	Phosphoric Acid (H ₃ PO ₄) Percent			Before Accelerated Weathering	After Accelerated Weathering	
0.27.....	0.20	80	2	1.1	1.1	9
0.67.....	0.50	80	2	1.9	1.9	8
0.94.....	0.70	80	2	2.2	2.0	7
0.27.....	0.20	150	2	3.9	3.4	7
0.67.....	0.50	150	2	3.2	2.6	7
0.94.....	0.70	150	2	4.3	2.8	8
0.27.....	0.20	200	2	3.9	3.4	7
0.67.....	0.50	200	2	5.2	2.7	3
0.94.....	0.70	200	2	5.9	1.8	2
0.67.....	0.50	80	2	2.6	2.5	9
0.67.....	0.50	80	6	3.3	3.2	10
0.67.....	0.50	80	10	3.6	3.2	10
0.67.....	0.50	150	2	4.3	2.8	9
0.67.....	0.50	150	6	5.0	3.3	10
0.67.....	0.50	150	10	5.6	3.6	9
0.67.....	0.50	200	2	7.7	3.0	2
0.67.....	0.50	200	6	7.7	3.4	2
0.67.....	0.50	200	10	7.0	3.4	2

dichromate (0.67 percent), and phosphoric acid (0.5 percent); and sodium nitrite (0.5 percent) and diammonium phosphate (0.5 percent) were run for comparison purposes. The results are shown in Table 4.

Discussion

Most accelerated weathering systems have the disadvantage that the results obtained cannot be correlated with a high degree of significance with those obtained under actual weathering conditions. The system used in this study (20 washes with distilled water) is representative of a heavy rainy period (approximately 5 inches). Difficulties are also experienced in corrosion rating. It was intended in the present study to present photographs showing examples of panels for each numerical rating, but it was found that it would be necessary to use color photography to adequately show the differences. The problem of numerical rating was simplified to some extent because the same type of rust, a thin adherent coat, usually formed on the rusted panels.

The results of Tables 1, 2 and 3 show no correlation between the amount of phosphate formed, either before or after accelerated weathering, within systems or between systems. The diammonium phosphate-sodium nitrite system shows the best rust inhibition and has the advantage that it offers very good corrosion resistance at room temperature, whereas the other two systems are most efficient at high temperatures. The sodium dichromate-phosphoric acid mixture was better than phosphoric acid alone.

In view of the good performance of the sodium nitrite-diammonium phosphate bath, tests were made to determine the rust inhibition of other common phosphates. The results in Table 4 show that mixtures of di and mono-sodium phosphates with sodium nitrite over a pH range of 5.3 to 7.5 produce better corrosion resistant coatings than the sodium dichromate-phosphoric acid pretreatment and in the pH range 6.3 to 7.2 were as good or better (80-95 washes to produce rust) than the diammonium phosphate-sodium nitrite system (80 washes to produce rust).

The other common phosphates used produced relatively little rust inhibition. The method of continu-

TABLE 3
Coating Thickness and Corrosion Resistance of
Sodium-Nitrite-Diammonium Phosphate Pretreatment

Concentration on Anhydrous Basis	Diammonium Hydrogen Phosphate (NH ₄) ₂ HPO ₄ percent	Temperature °F	Time of Immersion minutes	oz x 10 ⁻² of Coating as Anhydrous Phosphoric Acid (H ₃ PO ₄) per square foot		Corrosion Rating
				Before Accelerated Weathering	After Accelerated Weathering	
0.2.....	0.2	80	1	1.5	1.6	0-1
0.5.....	0.5	80	1	2.0	2.2	0-1
0.7.....	0.7	80	1	3.1	2.6	0-1
0.5.....	0.5	78	1½	2.6	2.5	0
0.5.....	0.5	78	1	3.3	2.6	0
0.5.....	0.5	78	2	4.5	3.3	0
0.5.....	0.5	78	4	5.0	4.7	0
0.5.....	0.5	120	1½	2.9	2.3	0
0.5.....	0.5	120	1	3.2	2.3	0
0.5.....	0.5	120	2	3.6	3.0	0
0.5.....	0.5	120	4	4.6	3.6	0

TABLE 4
Comparison of Various Pretreatments for Rust Inhibition

Treatment Number	Bath Composition Percentages on Anhydrous Basis	Temperature of Bath in Degrees F.	pH	Number of washes to produce rust with rating of 2
1	Phosphoric acid (1.0 Percent).....	200	1.6	3
2	Sodium dichromate (0.67 Percent) Phosphoric acid (0.50 Percent).....	200	2.1	20
3	Diammonium phosphate (0.5 Percent).....	App. 80	7.7	3
4	Sodium nitrite (0.5 Percent).....	App. 80	6.9	3
5	Diammonium phosphate (0.5 Percent) then second bath of sodium nitrite (0.5 Percent).....	App. 80	..	12
6	Sodium nitrite (0.5 Percent), then second bath of diammonium phosphate (0.5 Percent).....	App. 80	..	80
7	Sodium nitrite (0.5 Percent) Diammonium phosphate (0.5 Percent).....	App. 80	7.8	80
8	Sodium nitrite (0.5 Percent) Disodium phosphate (0.5 Percent).....	App. 80	9.0	10
9	Sodium nitrite (0.5 Percent) Disodium phosphate (0.43 Percent) Monosodium phosphate (0.07 Percent).....	App. 80	7.5	28
10	Sodium nitrite (0.5 Percent) Disodium phosphate (0.40 Percent) Monosodium phosphate (0.10 Percent).....	App. 80	7.4	44
11	Sodium nitrite (0.5 Percent) Disodium phosphate (0.37 Percent) Monosodium phosphate (0.13 Percent).....	App. 80	7.2	91
12	Sodium nitrite (0.5 Percent) Disodium phosphate (0.25 Percent) Monosodium phosphate (0.25 Percent).....	App. 80	6.7	95
13	Sodium nitrite (0.5 Percent) Disodium phosphate (0.13 Percent) Monosodium phosphate (0.43 Percent).....	App. 80	6.3	81
14	Sodium nitrite (0.5 Percent) Disodium phosphate (0.07 Percent) Monosodium phosphate (0.43 Percent).....	App. 80	5.9	69
15	Sodium nitrite (0.5 Percent) Disodium phosphate (0.03 Percent) Monosodium phosphate (0.47 Percent).....	App. 80	5.6	66
16	Sodium nitrite (0.5 Percent) Monosodium phosphate (0.5 Percent).....	App. 80	5.3	56
17	Sodium nitrite (0.5 Percent) Trisodium phosphate (0.5 Percent).....	App. 80	11.4	5
18	Sodium nitrite (0.5 Percent) Tetrasodium pyrophosphate (0.5 Percent).....	App. 80	10.4	4
19	Sodium nitrite (0.5 Percent) Sodium tripolyphosphate (0.5 Percent).....	App. 80	9.7	5
20	Sodium nitrite (0.5 Percent) Sodium hexametaphosphate (0.5 Percent).....	App. 80	7.0	8

TABLE 5
Rust Ratings for Phosphoric Acid Pretreatment
(0.4%), 200° F, 2 Min. Immersion

Panel Number	OBSERVERS		
	A	B	C
182.....	5	6	5
183.....	6	5	5
184.....	6	7	5
185.....	4	5	4
Mean.....	5.3	5.8	4.8
Mean of observers over panels 5.3.			

ing washing until rust occurs accentuates the difference in corrosion resistance of the various systems.

There was good agreement among the observers. Excluding sets of panels with ratings of one or less and ten for which good agreement would obviously be expected, there were 10 percent of the sets for which differences of average ratings greater than

two occurred between any two observers. In 25 percent of the cases, the greatest average difference was between one and two. The differences between observers was not a significant factor in rating of the sets. A typical example of the rating of a set is shown in Table 5.

Electron diffraction studies made by Cohen¹ indicate that the passive film formed by sodium nitrite solution on iron is $\gamma - \text{Fe}_2\text{O}_3$ with a small amount of $\gamma - \text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$. In this study the iron was immersed for 48 hours in the nitrite solution. It is postulated by the authors that the very good inhibition of the combination of nitrite and phosphate may be due to a double layer of an inner layer of an oxide of iron (FeO or Fe_2O_3), with a superimposed layer of ferrous phosphate. Panels coated with either alone rust after three washes compared with 80 or more for the combination, or for nitrite followed by phosphate. If phosphate is followed by nitrite, rusting occurs after 12 washes. It is concluded that in the treatments

covered by this study the nature of the coating formed is of much greater significance in rust inhibition than the amount formed.

A combination of diammonium phosphate and sodium nitrite has been used in the wet sand blasting of ships.²

Acknowledgment

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The views expressed by the authors are their own and do not necessarily represent the views of the Department of the Navy.

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1. M. Cohen, *Phys. Chem.*, **56**, No. 4, 451-3 (1952) April.
2. General Specifications for Building Vessels of the United States Navy, Appendix 6 of 2, Nov. 1951, page 4.

Figure 6—Equalizer tube gas lift valve.



Abstract

Conditions in gas lift wells producing appreciable proportions of water are reviewed. Principal corrodent is reported to be carbon dioxide and certain peculiarities of gas lift wells are enumerated. Because of the importance of the ionic composition and chemical content of produced waters, especially those of Gulf Coast wells, the scaling problem associated with these wells is an important consideration in devising inhibitive practices.

Because a current statistical analysis indicates about 4000 Gulf Coast gas lift wells probably are already corrosive and because it is expected that 16,000 ultimately will be corrosive the authors point out a potential corrosion damage of as much as \$16,000,000 annually.

Chemicals used to inhibit corrosion in these wells must have the faculty of penetrating the column of oil and water standing in the well. Laboratory experiments using a model gas lift well and actual produced fluids are described. Some currently available inhibitors have the disadvantage of forming insoluble salts with the calcium and magnesium ions and thus their use is precluded. Furthermore these compounds have not proved stable at reservoir temperatures.

Arsenical inhibitors consisting of solutions of sodium arsenite and sodium polyphosphate which proved in tests to be an adequate inhibitor, subsequently were the cause of such difficulties, their use was abandoned generally. Continued tests in two wells indicated they could be used when properly diluted if treatment was continuous and batch fed. Arsenic precipitation was seen as a possible bad effect but reversion of polyphosphates was not encountered. Further there was some suspicion arsenic from these inhibitors resulted in the poisoning of the catalyst in a catalytic cracker. Subsequently it was learned the standard electrical desalting process effectively removes the arsenic.

Investigations of organic polar compounds weighted with ethylene glycol resulted in the Continental Oil Company developing its own inhibitors. One of these is being tested in a 7600-foot well.

Corrosion Control in Gas Lift Wells*

II. Evaluation of Inhibitors

By D. A. SHOCK and J. D. SUDBURY

SINCE THE initial discussion of corrosion difficulties in gas lift wells,¹ there has been increasing evidence that the deeper oil well production is corrosive when appreciable quantities of water are being produced.

Historically, it is interesting to note that Buchan² relates that considerable work was done in the 1930's on the problem of finding materials of construction for sweet oil wells, although sweet oil wells were not generally considered corrosive. Prange³ specifically noted the causative agents in corrosive oil wells as early as 1946. In 1949, the problem had become of sufficient recognition that TP-IC was formed. The problem has been under study by this group and considerable progress has been made in defining the nature of the corrosion and methods of mitigation. From this study, it is evident that in the oil wells where the wellhead pressures are relatively low (500 pounds), the corrosion rate is usually not severe until the water production is greater than 50 percent. The corrodents are identified as lower fatty acids and carbon dioxide. However the critical pH for corrosive oil wells has not been defined as it has for condensate wells. The committee has reported that some oil wells producing at high pressures demonstrate corrosive tendencies. The wells which come under this classification are not usually produced by gas lift and will not be discussed in this paper.

Properties of Corrosive Gas Lift Wells

Corrosive gas lift wells fall in the general classification of corrosive low pressure sweet oil wells and according to Bilhartz and Greenwell^{2,4} are classified as water dependent corrosive wells. It is not the purpose of this article to leave the impression that the gas lift corrosion problem is unique to itself. The situation is rather that gas lift corrosive wells are a part of the general sweet oil corrosion problem.

The installation of gas lift valves usually coincides with production of appreciable water. For this reason, a severe corrosion problem often starts with installation of flow valves.

From the present understanding of the corrosive oil well mechanism, several generalizations on the factors influencing the corrosion rate in gas lift wells can be made. The major contributing corrosive agent as mentioned before is carbon dioxide gas which serves to supply large quantities of hydrogen ions when the conditions for solution are optimum. It has been pointed out previously¹ that the solubility of carbon dioxide will change with temperature and

* A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Tulsa, Okla., October 7-9, 1953.

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pressure. Therefore the acidity or corrosivity of the water changes with depth and the maximum corrosive zone changes with the individual well characteristics. It has been shown that iron analysis and surface coupons do not properly evaluate the severity of the subsurface corrosion.^{2,4} The down-hole coupon method was developed¹ to evaluate this severity.

Further complications have been brought out in that the gas lift gas may contain sufficient quantities of carbon dioxide to cause corrosion even if the produced gas is relatively free from carbon dioxide. The carbon dioxide in the gas lift gas also may cause corrosion on the exterior of the tubing and on the interior of the casing if condensed water in the gas filled space of the annulus becomes sufficiently acid.

The quantity of water being produced influences the corrosion rate in that first the critical oil-water ratio must be reached and second the greater volume of water produced results in a higher corrosion rate. This critical ratio is probably that ratio at which water begins to form a continuous film on the pipe surface. This continuous film permits chemical reaction and solution of the iron. The influence of the quantity of water is evident in that more corrosive contacts the pipe at greater velocities so that corrosion rates are increased by the effect of chemical reaction and rapid removal of any semiprotective films.

The ionic composition of the water can possibly change the corrosive character of a well. By this is meant that, with the same partial pressure of carbon dioxide and bottom-hole conditions of temperature and pressure, different ionic compositions of the produced water could keep corrosion from proceeding in one case or could have no influence in the other. It has been shown that some produced waters are of such ionic composition that it is impossible to bring them to pH values less than 5.5 even under partial pressures of several atmospheres of carbon dioxide.^{5,6} On the other hand most Gulf Coast waters from deeper formations are not of this type, and corrosion is not reduced appreciably by natural buffering.

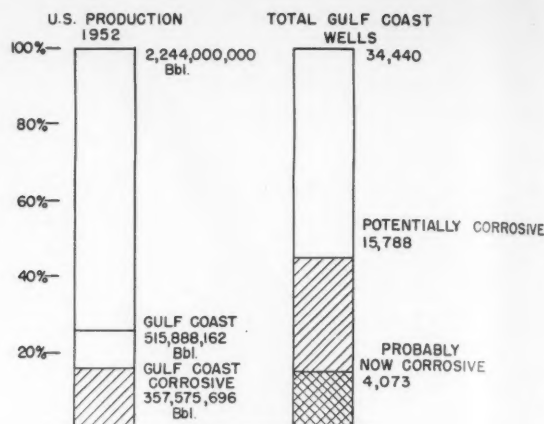


Figure 1—Comparison of corrosive and non-corrosive production.

TABLE 1
Comparison of Corrosive-Noncorrosive Production
Gulf Coast Oil Wells*

	1951 Production Barrels Oil	Wells Flow	Wells Art. Lift	Total Wells
Total Gulf Coast Production.....	515,888,162	17,139	17,301	34,440
Corrosive Production (Deeper than 4500 ft.).....	357,575,696	11,715	4,073	15,788
Corrosive Gulf Coast Production (percent of total).....	69.4%	....	....	45.6%

* Data compiled from Statistics of Oil & Gas Development and Production, 1951, Vol. 6, AIME, R.R. Commission Districts I, II, III, and IV of Texas and Southern Louisiana.

Ionic composition, however, can alter the comparative severity of attack so predictions of corrosion based on bottom-hole conditions and partial pressure alone have been in error because of this factor.

A large proportion of the Gulf Coast waters are relatively saline, containing from 30,000 to 100,000 ppm total solids. They usually are saturated in respect to calcium bicarbonate at bottom-hole conditions, contain appreciable quantities of magnesium and usually contain small amounts of barium and strontium. As the pressures drop from the formation to the surface, a scaling condition exists in various points of the production system. While the scale problem usually is most severe beyond the wellhead and through the separators to the battery, it exists sometimes in the well. Scale buildup in the annular space and in the flow valves is a definite problem; so that in the operation of gas lift wells, the corrosion and scale problems are tied together and are in reality related phenomena. Any treatment method for gas lift wells should consider both problems.

Economic Importance of the Problem

Greenwell recently reported to TP-IC⁴ that 30 percent of the country's low pressure sweet oil wells may be economically affected by corrosion.

In this paper, attempts at more specific estimates have been made. Assuming that all the Gulf Coast wells of greater than 4500 feet depth are potentially corrosive, Table 1 and Figure 1 were compiled to summarize pertinent well and production data. These

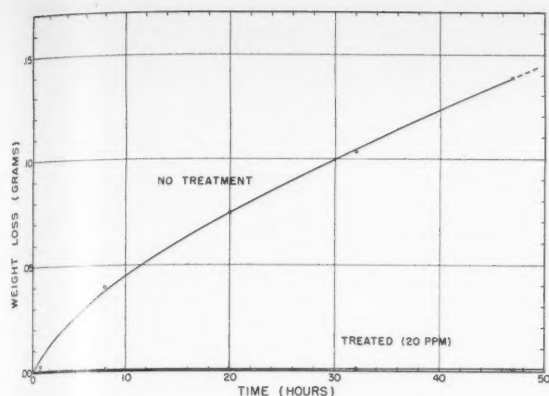


Figure 2—Corrosion rate curves. (One atm. carbon dioxide—produced oil and brine.)

TABLE 2—Typical Water Analysis

	p.p.m.
Total Solids	52,000
Chloride	29,700
Sulfate	5
Carbonate	0
Bicarbonate	350
pH	6.8
SpGr	1.038
Fatty Acids as Propionic	150
Sodium	16,800
Potassium	500
Calcium	1,540
Magnesium	1,140
Barium	280

data were taken from 1951 American Institute of Mining and Metallurgical Engineers' statistics.⁷

From these data, it is apparent that 11.6 percent (about 4000) of all Gulf Coast wells probably are already corrosive and 45.6 percent (or 16,000) are potentially corrosive. Assuming an annual cost due to corrosion of \$1000 per well per year, it is evident that a \$4,000,000 corrosion problem is imminent. Potentially, this could be \$16,000,000 per year.

Requirements of Treating Chemical

The discussion of this paper will consider the use of liquid inhibitor for treating gas lift wells. While it is recognized that this is not the only method possible, liquids have proved so satisfactory in treating other corrosive wells that it seems preferable to use them. Some of the discussion will be applicable to any type of inhibitor. However, it is recognized that inhibitors introduced by stick injection or through macaroni strings need not meet all the requirements necessary for an annular space liquid inhibitor.

The difficulty of making the treating chemical fall through the standing fluid column was discussed in a previous paper.¹ In most gas lift wells, the fluid stands in the annular space up to the operating gas lift valve. It was shown that a treating liquid must be able to penetrate this standing oil and water column. Where the gas lift valves are set on the bottom and operate therefrom, little difficulty is experienced in getting adequate penetration. But where the valves are set or operated several thousand feet off

bottom, penetration is a major problem. One important property for an inhibitor, therefore, is to have a fast diffusion rate.

Comparative diffusion rates are determined by dropping inhibitor into the annular space of the model gas lift well. The diffusion was measured as the time required for the inhibitor to pass through the column of oil field brine covered with an oil layer.

Evaluation of the inhibitor's effectiveness was done in the apparatus described previously.⁸ The weight change curves are determined in an apparatus which contains both the produced oil and water and carbon dioxide at one atmosphere. This system is made anaerobic by bubbling methane and then carbon dioxide throughout a given evaluation period. Coupons are removed through a gas lock to prevent the entry of air. They are examined under the microscope to determine if any pit attack takes place and weighted to determine the over-all loss of metal due to corrosion.

Figure 2 shows the typical weight loss curve at 120 degrees F in 50 percent produced oil and water. This rate is representative of a severely corrosive well. In the typical evaluation of a gas lift well inhibitor, the water and oil used is from the Slick-Wilcox Field, Goliad County, Texas. The analysis is shown in Table 2. A typical good protection case is also shown in Figure 2 for comparison.

A number of difficulties with inhibitors being offered on the market have been found when they are applied to the gas lift wells. Besides the problem of density, one of the greatest difficulties is in the interaction between the constituents in the water and the inhibiting compounds. Many of the polar nitrogen types and the sodium sulfonate soaps form insoluble salts with the calcium and magnesium ions which render them ineffective as inhibitors. Lengthy contact of inhibitor and water intensifies these reactions and precludes use of compounds of these types.

Another difficulty is that some of the compounds are not stable at reservoir temperatures or will not form protective films at these temperatures. For instance, the corrosion rate curve of one common inhibitor showed little protective effect at 170 degrees F but at 120 degrees F was one of the best tested. In one case, corrosion rates actually were accelerated by a surface tension reducer which decomposed at the 120 degree F of the test. Finally, there must be no evidence of differential or pit attack developed from the treatment or because of changes in operating conditions.

In summary, the requirements are that a chemical mixture must be produced which will sink rapidly through the annular fluids, not react with them and then be economically effective in reducing corrosion at 200-350 degrees F.

The Arsenical Inhibitors

The first laboratory and field tests, run about two years ago and briefly reported,¹ indicated that a commercially available inhibitor which was a solution of sodium arsenite and sodium polyphosphate was an

answer to the problem. This composition contained not only the inhibitor but an agent which reduced scaling. Continued work with this compound uncovered numerous difficulties and secondary effects which made it less attractive.

Because there still is considerable debate over the use of this type of inhibitor, it is thought that all observations by the authors on its behavior may be of interest to the industry.

First evidence of possible difficulty was noted in the coupons from the wells under treatment. Figure 3 shows several coupons from these wells. The edges are partially gone while the major portion of the coupon was completely protected. Both wellhead and down-the-hole coupons showed this effect; so the use of the compound throughout fields operated by the author's company was stopped. Two wells were reserved for experimental purposes, and several organic type inhibitors were run in these wells after use of the arsenic-type inhibitors was discontinued.

In the experimental wells, no corrosion difficulties were experienced. In several other wells in which the arsenical inhibitor was used and discontinued, corrosion failure by perforating the tubing was experienced. A typical failure is shown in Figure 4. The failures all showed a high incidence of differential attack, particularly at the upset region as shown in the figure. Wells which were continually treated, however, did not perforate; and after about eighteen months, one was pulled and the tubing inspected. No differential attack was found on any of the pipe.

During the time when arsenic was used in these wells, difficulty was encountered in injecting the concentrated solution at a slow rate, since the carbon dioxide in the gas lift gas made the solution sufficiently acid to precipitate practically pure As_2O_3 scale. This scale caused failure of the chemical injection pump and in one instance caused sticking of a Christmas tree wing valve. This difficulty was overcome by diluting the inhibitor with the produced water, which served to delay the precipitation. Lubricating the total daily inhibitor requirement batchwise was found to be a much better method of injection and overcame the difficulty of scaling in the feeder. Tubing from the experimental well mentioned was inspected and showed some accumulation of solid on the exterior (Figure 5). It is evident that some reaction took place in the gas zone in the well and precipitated out As_2O_3 here. Figure 6 shows the remains of the gas tube of a gas lift valve which corroded by pit attack.

The possibility of reversion of the polyphosphate to orthophosphate causing deposition was considered. Although numerous deposits have been analyzed, no scale has been found in the well system or flow lines which contain phosphates. It was concluded that the arsenic precipitation could be a problem, but the reversion of polyphosphates does not cause operating difficulties.

About the same time the pitting attack difficulties were being encountered in the field, difficulties were encountered at the Lake Charles refinery with poisoning of the cat cracker catalyst. It was found that arsenic in the crude could have been responsible in

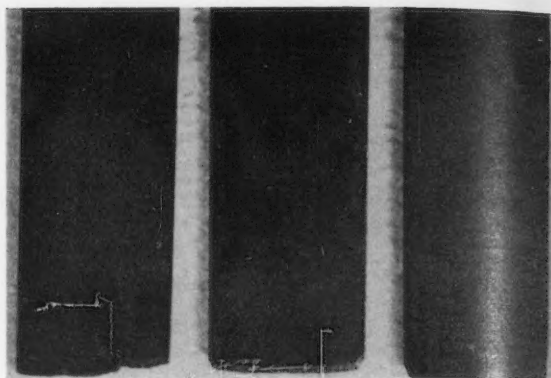


Figure 3—Corrosion coupons from arsenic-inhibited wells.



Figure 4—Tubing failure from arsenic-inhibited well.

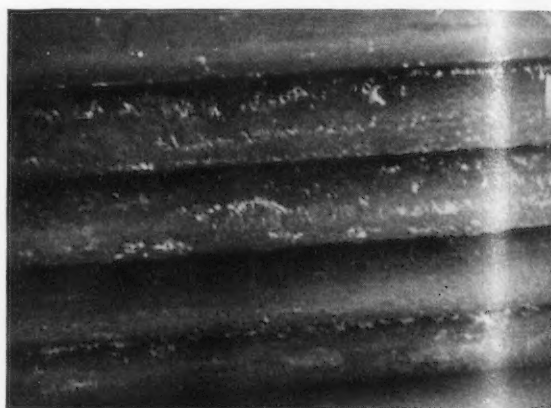


Figure 5— As_2O_3 scale on exterior of tubing.

concentrations of as low as eight parts per billion and consequently the use of arsenic for inhibition was looked on in disfavor. Since then however, it has been determined that the arsenic is effectively removed in the standard electrical desalting operation, so the use of arsenic compounds is more tolerable.

These arsenical inhibitors were tested in the laboratory and found to produce excellent protection curves at concentrations of 50 ppm in the water phase. At 5 ppm, differential attack starts to show up as pitted areas which are accentuated if fresh corrosive solution contacts the coupon. Figure 7 shows a photomicrograph of the pit attack noted at 5 ppm after only 24 hours exposure.

The conclusions reached on the use of arsenical inhibitors were that they would be effective if diluted properly, batch lubricated and sufficient concentration maintained. It is thought that the inclusion of some polar organic material would help reduce possible differential attack. The main advantages are low cost, temperature stability, ability to go through



Figure 7—Laboratory coupon. 5 ppm arsenic treatment. Approx. X 25.

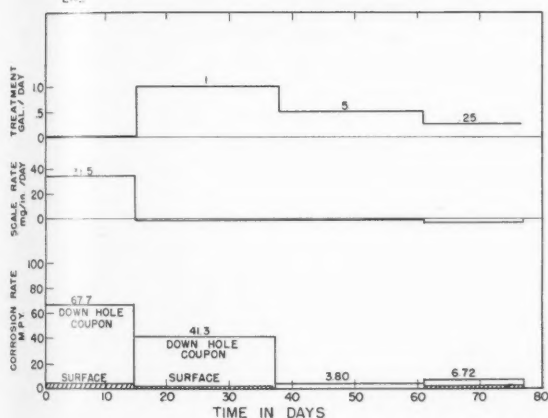


Figure 9—Effect of inhibitor Conoco T-12.

a high water column and effectiveness. The disadvantages are in handling, possible difficulties encountered in producing high arsenic content scale with subsequent damage, and possible bad effects on the catalysts in refineries if not removed before feeding to the cat cracker.

Weighted Polar Organic Inhibitors

Because of the difficulties encountered with arsenical inhibitors, attention was turned to the organic polar inhibitors. None of the commercially available inhibitors are compounded to fall through an oil and water column of an operating well. Consequently, work was started to overcome this difficulty and also to compound an effective inhibitor. This finally led to Continental Oil Company developing a series of inhibitors of its own.

One of the simplest means of producing an effective weighted inhibitor was to add ethylene glycol in sufficient quantity to make a mixture more dense than the produced water. If one commonly used polar organic inhibitor with density .90 is blended

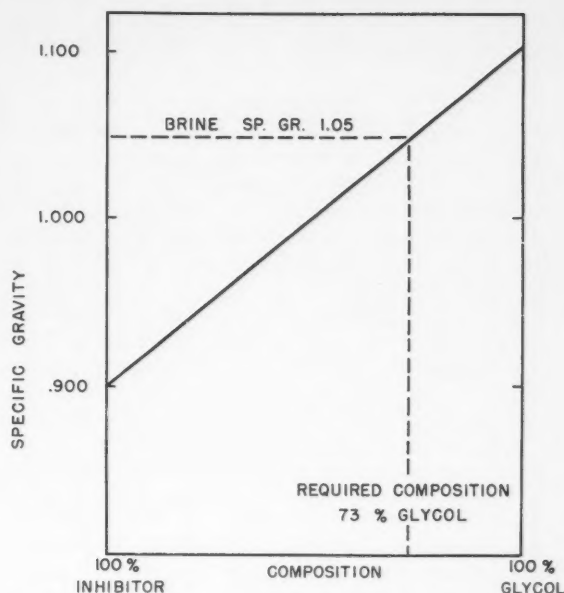


Figure 8—Composition requirements for weighing inhibitor with ethylene glycol.

with ethylene glycol, any density up to that of the glycol can be obtained by varying the percentages of ethylene glycol. Figure 8 shows the compositions required to achieve a given density. By knowing the density of the produced water, the required amount of ethylene glycol can be added to weight this inhibitor. Adding the glycol also renders the inhibitor sufficiently oleophobic to resist immediate solution in oil so the inhibitor is not lost because it is intercepted by the oil floating on the column of produced water. Using the same principle, other inhibitors have been compounded containing other polar groups. It has been possible to formulate a polyphosphate agent with these and alleviate the scaling problem.

One Continental Oil Company composition which has filled all requirements that can be evaluated by laboratory methods has been under field test for the past six months. The results are summarized in Figure 9. The well is 7600 feet deep with gas lift valves set at approximately 4000 feet. About 65 barrels of oil, 450 barrels of water and 500 MCF of gas per day is produced.

Coupons were set at the surface, below the bottom gas lift valve and at the battery. Corrosion rates are ordinarily very high just below the gas lift valves in these wells and scale forms at the battery as indicated on the graph in the period of zero inhibitor additive.

Inhibitor was lubricated into the annular space at the rate of one gallon per day for 21 days, then reduced to $\frac{1}{2}$ gallon per day for 24 days and then further reduced to $\frac{1}{4}$ gallon for 16 days. The greatest effect is noted on the down-the-hole coupons which gave 95 percent protection after being brought under control. The addition of $\frac{1}{4}$ gallon per day, while maintaining the corrosion protection rate at 90 percent was insufficient to maintain a satisfactorily high

degree of protection. The calcium carbonate scale deposition at the battery seems to have been controlled throughout the test.

Conclusions

1. It is evident that this problem is still in its early stages. Some 4000 wells probably are now corrosive and 16,000 may become so. An immediate \$4,000,000 per year replacement cost due to corrosion seems to be facing the industry. The potentially corrosive wells in 1951 produced 16 percent of the U. S. oil.
2. The problem of establishing corrosion control of these wells is of sufficient economic importance to warrant special development of a specific treatment.
3. The arsenical base inhibitors have merit but numerous disadvantages must be recognized.
4. A polar organic type has been developed and the first field tests indicate it is satisfactory and effective.
5. The laboratory evaluation methods have again proved successful in designing suitable treatments for specialized field problems.

Acknowledgment

The authors express their appreciation to Continental Oil Company field personnel who have carried out these tasks and without whom the program could not have succeeded.

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Oxidation of Plain, Alloyed And Ductile Irons at 1300 Degrees F*

By J. A. CAMERON*

Introduction

PRIOR TO the undertaking of this program scattered reports had been received indicating that the oxidation resistance of the new types of cast iron containing spheroidal graphite and commonly called ductile iron was much better than that of plain and alloyed irons containing flake graphite. As a result of these reports it was decided that an experimental program aimed at quantitative measurements of the oxidation resistance of a variety of cast irons would be undertaken.

Test Program

The chemical analyses and room temperature mechanical properties of the materials tested are shown in Tables 1 and 2. These materials included plain gray iron, unalloyed ductile iron, high silicon ductile iron, Ni-Resist and ductile Ni-Resist as well as two samples of carbon steel and one of AISI Type 405 stainless which was included to provide a base line for comparison.

Figure 1 illustrates the test specimen. Several specimens were assembled in a test rack having side rails inserted in the slots in the ends of the specimen.

In order to determine the amount of metal lost due to oxidation, the thickness of the unexposed specimens was measured with micrometers, and after exposure the specimens were sectioned and the thickness of unoxidized metal measured microscopically. The manner in which the specimens were sectioned is indicated in Figure 1. The data resulting from these measurements were translated into inches per year penetration by using the following equation:

$$\text{ipy} = \frac{(\text{original thickness} - \text{final thickness})}{2} \times \frac{8760}{t}$$

where 8760 = Hours per year

t = Hours of exposure

2 = Factor required because of oxide penetration from both sides of specimen

Exposures were made in a Leeds and Northrup Homo Tempering Furnace which is equipped with a fan for circulation of air. Due to the necessity for using the same furnace for other work, it was not possible to expose the specimens for the desired time periods continuously. There was considerable variation but the average exposure period was about 150 hours.

The temperature of 1300 degrees F was selected because oxidation characteristics of these materials

Abstract

Oxidation tests of up to 4000 hours duration at 1300 degrees F were made on ordinary flake graphite gray irons, ductile iron, and on highly alloyed cast iron having both flake and spheroidal graphite. It is concluded that ductile irons possess resistance to oxidation markedly better than that of flake graphite irons. In highly alloyed irons the difference is less pronounced at this temperature. Specimens exposed in atmospheric tempering furnace equipped with fan for circulation of air.

at this temperature were of considerable interest in some of the products manufactured by author's company. At the outset it was intended that the tests would be of 1000 hours' duration, but after examining the results of this exposure it was decided that the program should be continued to longer times and some of the tests were carried on to 4000 hours.

Test Results

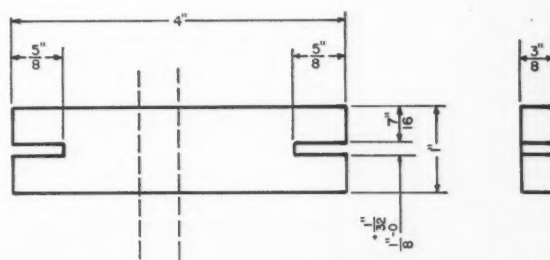
The oxide penetration data resulting from these tests are shown in Table 3 in both actual penetration and calculated ipy values. In the case of materials 1 through 9, the 1000-hour and 4000-hour measurements are on the same sample while the 2000-hour measurements are from a duplicate specimen. When the specimens were sectioned for the second time, the cut was made far enough (about $\frac{3}{8}$ -inch) from the end to avoid irregular results due to end effects. For materials 12 through 19, both measurements were obtained from the same specimen.

The test results shown for inches penetration represent penetration from one side. The total metal thickness lost has been divided by the factor of 2 indicated in the preceding equation.

Figure 2 is graphical representation of the actual penetration data and Figure 3 shows the inches per year figures plotted against length of exposure.

Discussion and Conclusions

In discussing the results and interpretation of



SECTIONS FOR MEASURING AFTER EXPOSING

Figure 1—Oxidation test specimen.

*A paper presented at the Tenth Annual Conference and Exhibition, National Association of Corrosion Engineers, Kansas City, Mo., March 13-19, 1954.

*Chief Metallurgist, Elliott Company, Jeannette, Pa.

TABLE 1—Chemical Analyses of Materials Tested

SPEC. NO.	Name	C	Si	Mn	Mg	Cr	Ni
1	Ductile Iron, As Cast*	3.43	2.47	0.45	0.071	.....	1.02
2	Ductile Iron, Annealed*	3.43	2.47	0.45	0.071	.....	1.02
4	Ductile Iron, 4 Percent Si*	2.78	3.82	0.54	.....	.....	.....
5	Ductile Iron, 5.5 Percent Si*	2.62	5.59	0.41	0.048	.....	0.73
6	Ductile Type 2 Ni-Resist*	2.28	2.51	1.03	0.11	1.70	20.22
7	Ductile Type, 4 Ni-Resist*	2.10	5.58	0.29	0.10	4.42	29.40
8	Type 405 Stainless.....	0.055	0.78	0.75	.....	12.15	0.13Al
9	Type 2 Ni-Resist*	2.97	1.63	1.18	.....	1.89	20.02
12	Cast Steel.....	0.32	0.28	0.46	.....	.....	.....
13	Wrought Mild Steel.....	0.27	0.10	0.43	.....	.....	.....
14	Malleable Iron.....	1.45	1.29	0.88	.....	0.02	.....
18	Cast Iron 1.....	3.01	2.46	0.81	.....	.....	.....
19	Cast Iron 2.....	2.60	1.71	1.07	.....	.....	.....

* Samples Supplied By The International Nickel Company

TABLE 2—Mechanical Properties of Materials Tested

SPEC. NO.	Name	(PSI) Tensile Strength	(0.2 Percent) (PSI) Yield Strength	Percent Elongation
1	Ductile Iron, As Cast.....	99,500	75,000	1.5
2	Ductile Iron, Annealed.....	70,000	54,000	22.0
4	Ductile Iron, 4 Percent Si.....	(1)	.....	.....
5	Ductile Iron, 5.5 Percent Si.....	75,200	.....	1.
6	Ductile Type 2 Ni-Resist.....	65,000	35,000	28.
7	Ductile Type, 4 Ni-Resist.....	56,800	.....	5.
8	Type 405 Stainless.....	65,000	40,000	22.
9	Type 2 Ni-Resist.....	25,000	.....	.....
12	Cast Steel.....	70,000	36,000	22.0
13	Wrought Mild Steel.....	60,000	30,000	25.0
14	Malleable Iron.....	(1)	.....	.....
18	Cast Iron 1.....	30,000	.....	.....
19	Cast Iron 2.....	45,000	.....	.....

(1) No Data Available

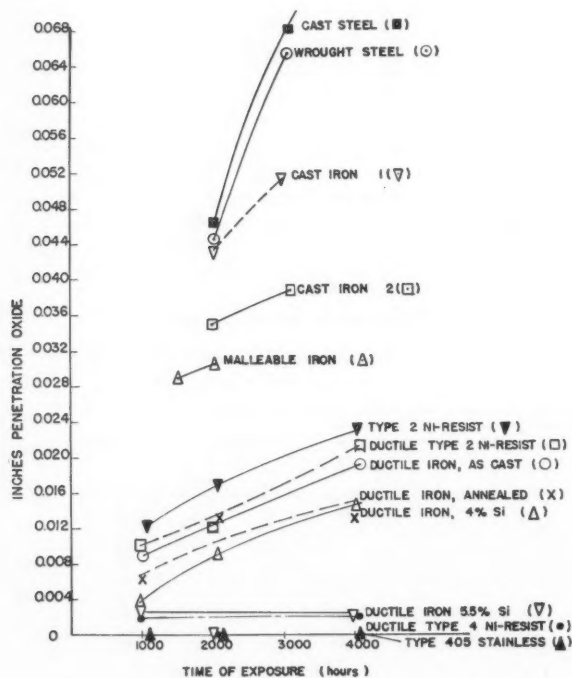


Figure 2—Metal loss vs. time of exposure at 1300 degrees F.

these oxidation tests, it is recognized that complete correlation between such tests and service experience is extremely difficult. It is believed, however, that the order of merit would remain about the same for the various materials, when in an environment composed principally of air and oxidizing gases. Relatively large proportions of other gases such as hydrogen sulfide or acid vapors might reverse the positions of some of the materials.

Furthermore, this investigation has not included a study of the strength properties of the various cast irons and steels at 1300 degrees F. Within these limitations the following observations may be made:

1. The oxidation resistance of ductile iron is markedly superior to that of ordinary gray iron containing flake graphite. Part of this increase may be attributed to increased silicon and nickel contents but much of it must be due to the difference in graphite structure. The oxidation of ordinary cast iron containing flake graphite may be visualized as progressing inward from the surface more or less uniformly until the metal-oxide interface reaches a graphite flake. This graphite flake is then oxidized entirely in a short time and then newly exposed metal surface is exposed to attack. Such an effect should be reduced in the case of ductile iron because the spheroidal graphite has a lower surface-to-volume ratio than flake graphite. Furthermore, the distance between graphite particles is greater for ductile iron. This increases the distance through which oxygen must diffuse before internal oxidation can take place and therefore reduces the rate of such oxidation.
2. At 1300 degrees F ductile Type 2 Ni-Resist is slightly more resistant to oxidation than the same alloy with flake graphite but the difference is considerably less than that between ductile and flake plain gray iron. This might not be true at higher temperatures. Other work by other investigators which is still in progress and therefore unpublished indicates that at higher temperatures in the range 1700-1750 degrees F the difference between the two grades of Ni-Resist is much greater than that reported here at 1300 degrees F. Apparently this latter temperature is too low to properly differentiate these materials.
3. Increasing the silicon content of ductile iron and Ni-Resist improves their resistance to oxidation at 1300 degrees F. A word of caution must, however, be added regarding the use of these alloys because they are highly sensitive to shock of either a mechanical or thermal nature. As is indicated in Table 2 the ductility of the high silicon ductile irons is quite low even though the graphite is spheroidal.
4. In the samples tested, increasing the silicon content reduced the oxidation resistance of ordinary gray iron. This observation is probably subject to limitation since the higher silicon iron was obtained by ladle additions of about 0.8 percent silicon. When silicon is added in this manner it functions

TABLE 3—Oxide Penetration at 1300° F

SPEC. NO.	Name	1000 Hr.		2000 Hr.		3000 Hr.		4000 Hr.	
		In.	ipy	In.	ipy	In.	ipy	In.	ipy
1	Ductile Iron, As Cast.....	0.009	0.078	0.012	0.053	.....	.....	0.019	0.042
2	Ductile Iron, Annealed.....	0.006	0.053	0.013	0.057	.....	.....	0.013	0.028
4	Ductile Iron, 4 Percent Si.....	0.004	0.035	0.009	0.039	.....	.....	0.015	0.033
5	Ductile Iron, 5.5 Percent Si.....	0.003	0.026	0	0	.....	.....	0.002	0.004
6	Ductile Type 2 Ni-Resist.....	0.010	0.088	0.012	0.053	.....	.....	0.019	0.042
7	Ductile Type 4 Ni-Resist.....	0.002	0.017	0	0	.....	.....	0.002	0.004
8	Type 405 Stainless.....	0	0	0	0	.....	.....	0	0
9	Type 2 Ni-Resist.....	0.012	0.105	0.017	0.074	.....	.....	0.021	0.046
12	Cast Steel.....	.....	.....	0.046	0.202	0.068	0.198	0.041 ⁽¹⁾	0.098
13	Wrought Steel.....	.....	.....	0.044	0.193	0.065	0.190	.....	.....
14	Malleable Iron.....	0.029	0.172	0.030	0.131	.....	.....	.....	.....
18	Cast Iron 1.....	(1480 hr.)	.....	0.043	0.188	0.049	0.142	.....	.....
19	Cast Iron 2.....	.....	.....	0.035	0.153	0.038	0.111	.....	.....

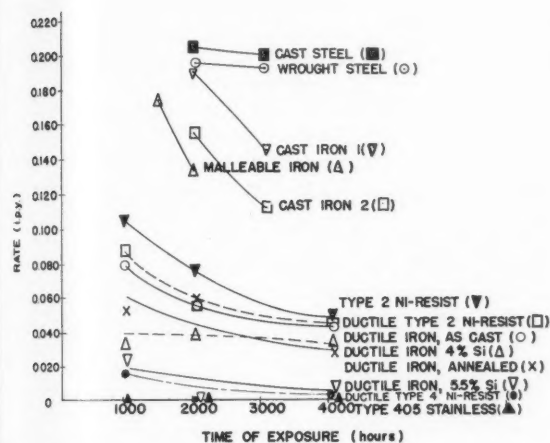
⁽¹⁾ Limit of internal oxidation.

Figure 3—Rate of oxidation vs. exposure time at 1300 degrees F.

as an inoculant tending to increase the graphite flake size. Different results might have been obtained if the silicon addition had been made in the cupola, in which case it would not have increased the graphite flake size.

5. Ductile iron of the usual composition has oxidation resistance at 1300 degrees F about equal to that of regular or ductile Type 2 Ni-Resist. In some instances this could result in a substitution of ductile iron for Ni-Resist, but in others where the high temperature strength or coefficient of thermal expansion of Ni-Resist is required such a change may not be feasible.
6. The oxidation resistance of ductile Type 4 Ni-Resist and ductile iron containing 5.5 percent silicon is about equal to that of Type 405 stainless steel at 1300 degrees F with all three materials being almost completely resistant.
7. At 1300 degrees F both of the ordinary gray irons were better than low carbon cast or wrought steel but none exhibited a degree of resistance that would be satisfactory in any but the crudest applications.
8. Reference to Figure 3 indicates that the rate of oxidation is decreasing with time. It may be assumed that if the tests had been continued to say 8000 hours, rates lower than those reported here might have been observed.

Acknowledgment

It is a pleasure to acknowledge the assistance of a number of people who have contributed generously to this study. First among these should be E. J. Vater who conducted the exposures and measured the specimens. C. T. Evans was Director of Development and Metallurgy at Elliott Co. at the time the investigation was undertaken. Many of the samples were furnished by F. G. Sefing who with his associates in The International Nickel Co. also assisted in making the measurements.

DISCUSSION

Question by James T. Dwyer, Jr., Gulf Oil Corp., Port Arthur, Texas:

In your formula for determining the oxidation penetration you have not included a correction for the growth in that direction. Would this not result in data showing better resistance to oxidation than actually is achieved?

Reply by J. A. Cameron:

To answer Mr. Dwyer's question directly, we would say that the oxidation rates reported were not corrected for growth and any error introduced thereby would, as suggested by Mr. Dwyer, be in the direction of giving an apparent oxidation rate lower than the true rate. In the absence of quantitative data, it is our opinion that any such error is very small, especially on those irons which are usefully resistant to oxidation at 1300 degrees F. As was indicated in Figure 1, the test specimens used were $\frac{3}{8}$ -inch thick. Since growth is at least partially a volumetric phenomenon while oxidation takes place only at or near the surface, the use of relatively thin specimens should minimize errors of the type suggested by Mr. Dwyer.

In a more general sense, it appears to us that corrections of oxidation rates for growth during exposure is considerably more difficult than may be immediately apparent. Perhaps this could be accomplished by exposure of duplicate specimens in non-oxidizing atmospheres, or by use of the ingenious marking devices used in diffusion experiments.

Discussion by K. D. Millis, Metallurgist, The International Nickel Co., Inc., New York City:

Mr. Cameron is to be congratulated on his disclosure which contributes much to our knowledge of the behavior of ferrous cast materials at elevated temperatures. His paper presents a clear evaluation of the relative heat resistance of the various materials and demonstrates the importance of the graphite form in the high carbon materials.

I would like to take this opportunity to supplement his data with the results of some similar tests conducted at temperatures up to 1750 degrees F. Specimens mounted in racks similar to those used by Mr. Cameron were exposed in a heat treating furnace at Washington Mould, Machine and Foundry Company. The racks were situated near the roof of the furnace in the immediate neighborhood of the con-

TABLE 1
Oxide Penetration of Ductile Iron and Other Materials at Elevated Temperatures

MATERIAL	Condition	C	Si	Mn	Ni	Mg	Other	OXIDE PENETRATION INCH PER YEAR	
								Test A	Test B
Ductile Iron.....	As-Cast	3.43	2.47	0.45	1.02	0.071	.....	0.482	0.693
Ductile Iron.....	Annealed	3.43	2.47	0.45	1.02	0.071	.....	0.525	0.669
4 Percent Si Ductile Iron	Annealed	2.51	4.13	0.48	.....	0.067	.....	No Test	0.430
6 Percent Si Ductile Iron	Annealed	2.88	5.83	0.36	.....	0.05	.....	No Test	Nil
6 Percent Si Ductile Iron	Annealed	2.62	5.59	0.41	0.73	0.048	.....	0.051	No Test
Gray Iron.....	.....	3.03	1.98	0.59	.....	0.208P	.....	Complete**	Complete*
Cast Steel.....	.....	0.29	0.26	0.49	.....	.....	.....	Complete**	0.665
Pearlitic Malleable Iron..	.....	2.27	0.93	0.98	.....	0.092Cr	.....	Complete**	1.02

Test Cycles 24 hrs. long—4 hour heat to 1750°F., 7 hours at 1750°F., furnace cool to 600-700°F. before next cycle started.

Test A—100 cycles

Test B—45 cycles

Note: Ductile iron shows a lower rate of penetration in a longer test presumably because the rate decreases at greater depths.

* Assuming that penetration became complete simultaneously with the end of the test, the rate would be 1.5-inches per year. The actual time of complete penetration is unknown and may have occurred much earlier in the test with a considerably higher rate of penetration.

** If in this case penetration became complete simultaneously with the end of the test the rate would be 0.7-inch per year. Again, the actual time of complete penetration is unknown and may have occurred much earlier in the test with a considerably higher rate of penetration.

trol thermocouple. The furnace was operated cyclically, each cycle consisting of a four hour heating period to 1750 degrees F which temperature was held for seven hours, followed by a cool to 600/700 degrees F before the start of the next cycle. Each cycle took a total of 24 hours and once a week the furnace was cooled to room temperature. Two separate racks were exposed, one for 45 cycles and the other for 100 cycles.

Measurements to determine the depths of oxide penetration were made in the same manner as outlined by Mr. Cameron. The depth figures were converted to inches of oxide penetration per year and are shown in Table 1.

Results of this work are in harmony with Mr. Cameron's findings that irons containing spheroidal graphite are considerably more resistant to oxide penetration at high temperatures than flake graphite irons, cast plain carbon steels and pearlitic malleable iron. The 100-cycle exposure was too long to establish firm figures for gray iron, cast steel and malleable iron since complete oxide penetration occurred at some unknown time during the exposure in each case.

This work also shows that increasing silicon con-

tent greatly improves the heat resistance of ductile iron. After 45 cycles the 6 percent silicon ductile iron had no measurable oxide penetration and was merely discolored. The 100-cycle exposure caused only 0.051 inches penetration per year in a 5.6 percent silicon ductile iron as compared with 0.482 ipy in regular ductile iron and complete penetration in gray iron, cast steel and the malleable iron. The use of these high silicon ductile irons must, however, be considered carefully, because silicon has a powerful embrittling effect on ferrite and at 6 percent silicon the iron has little resistance to mechanical shock at room temperature.

One other factor of note developed by Mr. Cameron's work and this work is the apparent protective nature of the oxide scale on spheroidal graphite irons as compared to steel and malleable. In 45 cycles the penetration rates of ductile iron and cast steel were about the same in the 1750 degree F tests. However, in 100 cycles the rate for ductile iron has decreased by about a third while the rate in steel has increased to an unknown extent. The rate for malleable iron was considerably higher than ductile iron at 45 cycles and while it may have decreased somewhat at 100 cycles, the extent of the decrease was not as great as that for ductile iron.

I appreciate the opportunity of presenting these data and am indebted to Mr. Seifing for advice during the tests and for his willingness to make the presentation.

Reply by J. A. Cameron:

The work described by Mr. Millis is that mentioned in the paper as in progress at the time the paper was written. These additional data do not appear to require comment except to express our appreciation for the contribution.

NACE TECHNICAL COMMITTEE REPORTS

Publication 54-3

First Interim Report of Technical Unit Committee T-4B On Corrosion of Cable Sheaths

Pipe-Type Cable Corrosion Protection Practices In the Utilities Industry

Compiled by Task Group T-4B-4 on Protection of Pipe-Type Cables*

Introduction

THE PIPE-TYPE cable is a relatively new but rapidly growing means of transmitting large blocks of high-voltage electric power. It consists primarily of a steel pipe welded into long lengths, provided with high quality external corrosion protection and usually buried in the earth. Three or more "solid type" paper-insulated cables are drawn into this pipe which is then filled with oil or gas maintained under pressure.

The advent of pipe-type cable has engendered corrosion protection problems unique thereto and various methods of solving them are in operation among the several utilities. Integrity of the pipe and therefore of the coating is of special importance because leaks cannot be tolerated and repairs are very costly and time consuming.

This summary presents pipe-type-cable corrosion protection practices of seventeen operators of pipe-type cable (estimated to cover more than 90 percent of the mileage of such cable in operation in the United States), compiled from replies to a questionnaire issued by Committee T-4B-4.

A. General Information

The following utilities submitted replies to the questionnaire:

Alabama Power Company—Birmingham, Alabama
Columbus and Southern Ohio Electric Company—Columbus, Ohio
Consolidated Edison Company of New York Inc.—New York, N. Y.
The Detroit Edison Company—Detroit, Michigan
Florida Power & Light Company—Miami, Florida
Long Island Lighting Company—Mineola, New York
Memphis Light, Gas and Water Division—Memphis, Tennessee
New Orleans Public Service Inc.—New Orleans, Louisiana
Northern States Power Company—Minneapolis, Minnesota
Pacific Gas and Electric Company—San Francisco, California
The Pennsylvania Railroad—Philadelphia, Pennsylvania

Abstract

Data received in reply to a questionnaire is compiled on the actual field practices of utilities operating pipe-type cables. The data cover more than 90 percent of this type of cable in operation at the time the survey was made. The principal data are tabulated, giving reports by seventeen operators on field practices. The subjects covered include size and kind of pipe, coating materials, holiday testing, potential surveys, cathodic protection, coating resistance measurements, rates of coating resistance depreciation, bonding, stray current measurements, shunts, surveys, voltages and magnitudes of cathodic protection currents and other information.

Philadelphia Electric Company—Philadelphia, Pennsylvania
City Public Service Board—San Antonio, Texas
Public Service Company of Northern Illinois—Chicago, Illinois
Public Service Electric and Gas Company—Newark, New Jersey
Tennessee Valley Authority—Chattanooga, Tennessee
Wisconsin Electric Power Company—Milwaukee, Wisconsin

For the 17 utilities reporting installations of pipe-type cables, the manufacturers of their cables were: General Cable, General Electric, Okonite, Phelps-Dodge.

For the 17 utilities represented, 73 pipe-type cables were reported installed as of approximately mid-1953. One installation was made in 1935, one in 1941, and one in 1945. The 70 others were installed subsequent to 1946, at the rate of approximately 10 per year.

The 17 utilities report having a total of 294.8 miles of pipe-type cable installed, with voltage distribution as follows:

Kv	15	23	46	69	115	138
Miles	2.5	1.8	0.7	85.0	31.9	172.9

The pipe-type cables reported are of two types, high pressure oil cables and high pressure gas cables. The cables of 11 utilities are all high pressure oil cables. The cables of 3 utilities are all high pressure gas cables. Three utilities have both high pressure oil and high pressure gas cables. Totals are 204.8 miles

*Frank Kahn, Philadelphia Electric Co., Philadelphia, Chairman.

of high pressure oil cables and 91.9 miles of high pressure gas cables.

Of the 279.3 miles of pipe-type cable for which pipe wall thickness is reported, 261.3 miles is substantially of 1/4-inch wall thickness, 12 miles is 3/8-inch wall thickness, and 6 miles is 3/16-inch wall thickness. Diameters of pipes range from 4 1/2-inch to 8 3/8-inch O.D. The number of miles of pipe of the various sizes and wall thicknesses are shown in Table A.

The average length of pipe between manholes for 14 utilities was 1620 feet, ranging from an average of 1220 feet to an average of 2800 feet for individual utilities. Two utilities reported their splices were not in manholes, but that average spacings of splices are 1400 feet and 1600 feet, respectively. One utility has short generator leads only.

B. Pipe Coating

The external pipe coating used by 14 of the 17 utilities reporting was Somastic (an asphalt mastic) coating. The oldest installation (1935) used No. 70B Bitumastic Enamel. Of the other two utilities, one used Barrett's Special Waterworks Enamel with two wraps of pipeline felt; the other utility used Bedford Grey Enamel, Bitumastic Enamel and Somastic coating, on different installations.

Eleven utilities reported the softening point of the electric insulating medium used in the pipe coating was as follows:

TABLE A

Wall Thickness In Inches	Miles of Pipe of Indicated, Outside Diameter, In Inches						
	4 1/2	5.0	5 5/16	6.0	6 3/4	7.0	8 3/4
0.187	...	...	...	...	6.0	...	...
0.237	3.8	...	...	...	...	...	...
1/4	...	10.0	20.7	12.0	65.3	13.9	99.6
0.258	...	...	24.0	...	...	...	...
0.280	...	...	...	...	12.0	...	...
3/8	...	...	...	...	12.0	...	...
Not given	5.4	4.9	...	...	...	...	...

2 used asphalt of melting point in the range 150-160 F.
2 used asphalt of melting point in the range 175-200 F.
5 used asphalt of 210 F melting point.
1 used plasticized coal-tar, softening point 235 F.
1 used Bitumastic enamel thoroughly liquid at 425 F.

Primers

The pipe-coating primers used and their methods of application are as follows. Primer used by 11 utilities for Somastic coating is asphalt in petroleum thinner. Of these, 3 report primer is sprayed on, 3 report primer is brushed on, one reports primer is sprayed or brushed on, depending on conditions, one reports primer is applied hot, one reports primer is applied cold. One utility reports using liquid asphaltic material painted on, as primer for Somastic coating. One utility reports using coal-tar cutback, rug-applied at pipe-wrapping mill as primer for Barrett's Special Waterworks Enamel. One utility reports using Bitumastic primer applied with a brush as primer for No. 70B Bitumastic Enamel. One utility reports using red lead on unburied pipe.

TABLE 1—A. General Information

1 & 2 Name and Address of Utilities Replying to Questionnaire

3-a Pipe-Type Cable Installations—Names of Manufacturers

3-b Pipe-Type Cable Installations—Year Installed

3-c & d Pipe-Type Cable Installations—Circuit Miles and Voltage

Company	Question A-3-a				Question A-3-b											Question A-3-c and d						
	General Cable	General Electric	Okonite	Phelps-Dodge	'35	'41	'45	'47	'48	'49	'50	'51	'52	'53	Total	15Kv	23Kv	46Kv	69Kv	115Kv	138Kv	AHV
A		x	x	x				3		4	2	4	8	4	25				14.4		55.2	69.9
B	x		x			1			2	1	2	1			7						42.6	42.6
C			x							2					2				3.5			3.5
D			x	x				1					3		4				~18.7		2.5	21.2
E			x	x						1	2				3					10.0		10.0
F	x	x	x	x				2	4		1			1	8				32.9			32.9
G			x	x					1	2			1	2	6		1.8	0.4		10.8		13.0
H				x								1			1					10.0		10.0
I				x				1					1	1	3				15.5			15.5
J	x							1							1					11.1		11.1
K			x								1				1						3.4	3.4
L	x	x							1				1		2						26.0	26.0
M			x		1										1						6.3	6.3
N	x		x	x									1		1					10.9		10.9
O		x							2						2					11.0		11.0
P			x	x				1		1	1			2	5	2.5		0.3				2.5
Q				x				1							1						5.0	5.0
Totals	6	4	10	10	1	1	1	9	11	10	9	7	14	10	73	2.5	1.8	0.7	85.0	31.9	172.9	294.8

Thicknesses

The nominal and minimum thicknesses of the pipe coating now considered acceptable are: For 16 utilities reporting, average nominal thickness was $1\frac{15}{32}$ -inch; average minimum acceptable thickness $\frac{3}{8}$ -inch. Eight utilities report nominal thickness $\frac{1}{2}$ -inch, four of these reporting $\frac{3}{8}$ -inch minimum acceptable thickness, two reporting $\frac{1}{2}$ -inch, and one less than $\frac{1}{2}$ -inch coating acceptable if it passes holiday detector set for $\frac{1}{2}$ -inch coating. Five utilities reported nominal thickness of $\frac{7}{16}$ -inch, three of these reporting $\frac{3}{8}$ -inch minimum acceptable thickness and one $\frac{7}{16}$ -inch. One utility reported a nominal thickness of $\frac{9}{16}$ -inch, with a minimum acceptable of $\frac{1}{2}$ -inch; one reported a nominal thickness of $\frac{3}{8}$ -inch, with a minimum acceptable of $\frac{1}{4}$ -inch; and one reported only a minimum acceptable thickness of 0.156-inch with no nominal value.

Outer Surfacing

Of 16 utilities reporting the type of protective outer surfacing applied to the pipe coating, 8 apply whitewash, 5 normally use no protective coating, one uses talc, one uses reinforced concrete coating on river crossings and one uses Johns-Manville tar-saturated pipe-line felt.

Coating of Welds

The methods used for applying the coating over field pipe welds are as follows. Of 17 utilities reporting, 14 have Somastic-coated lines and report that hot Somastic is applied over the weld in a mold. Of

these, 12 report using primer, 4 of them first clean the surface by wire-brushing, one heats the pipe surface and applies heated primer and one puddles the hot Somastic in the mold to remove trapped gases. One utility using Somastic reports primer is not used.

Three of the utilities reporting use enamel coatings. Of these, after using a primer, one wraps the joints with the enamel cigarette-fashion and then applies two thicknesses of asbestos pipe-line felt. The second uses a primer and then applies the enamel with a brush and sling. The third applies enamel and felt, using no primer.

Moisture Removal

When coating is applied over field pipe welds, the provisions made to remove moisture from the end surfaces of the original coating adjacent to the weld, by 15 utilities reporting, are as follows: Seven utilities dry these surfaces with a torch, 5 make no special provisions, one heats and trowels these surfaces, one applies the Somastic at 350 F, and one relies on removal of moisture as a result of heating the Somastic to make it pliable.

Treatment of Mold

Of 14 utilities reporting that they use a mold to apply Somastic coating to the pipe at field welds, 13 treat this mold to prevent the coating from sticking to the mold, 10 applying whitewash to the inside surface of the mold, 2 using vegetable oil, and one using kerosene.

3-e Pipe-Type Cable Installations—Type of Cable and Pressure Medium

3-f Pipe-Type Cable Installations—Pipe Size and Wall Thickness (Pipe thickness $\frac{1}{4}$ -inch unless otherwise noted)

3-g Pipe-Type Cable Installations—Average Length between Manholes (Figures in parentheses not included in total)

Question A-3-e	Question A-3-f							Question A-3-g		
	4½"	5.0"	5½"	6.0"	6½"	7.0"	8½"	Miles of Pipe Circuit Considered	Number of Lengths Between Manholes	Average Length Between Manholes, Feet
High Pressure Oil.....			3.2		15.1		51.3	67.0*	290	1220
High Pressure Gas.....						6.5	36.1	42.6	121	1860
High Pressure Oil.....					3.5			3.5	14	1320
High Pressure Oil.....			7.5	2.5	11.2			21.2	46	2430
High Pressure Oil.....			10.0					10.0	23	2300
7.1 Mi. H. P. Gas—25.8 Mi. H. P. Oil.....					32.9*			32.9	115	1510
High Pressure Oil.....	3.5 ^b		5.0 ^c	4.2				13.0	37	1850
High Pressure Oil.....		10.0						10.0	19	2800
10.6 Mi. H. P. Gas—4.9 Mi. H. P. Oil.....	5.4 ^d	4.9 ^d						15.5	27	3150
High Pressure Oil.....					11.1 ^e			(11.1) ^b		
High Pressure Oil.....					3.4			(3.4) ^c		
High Pressure Gas.....			8.0 ^c		18.0 ^f			26.0	97	1410
High Pressure Oil.....						6.3		6.3	25	1340
High Pressure Oil.....							10.9	10.9	26	2200
High Pressure Oil.....			11.0 ^c					11.0	41	1420
0.6 Mi. H. P. Gas—2.2 Mi. H. P. Oil.....				0.3	0.1	1.1	1.3	(2.8) ^d		
High Pressure Gas.....				5.0				5.0	16	1650
	9.2	14.9	44.7	12.0	95.3	13.9	99.6	274.9	897	Avg. 1620

* 0.9 mi. of pipe (4 river crossings) is of $\frac{3}{8}$ " wall thickness.

^b 0.237" wall thickness.

^c 0.258" wall thickness.

^d No pipe thickness given.

^e $\frac{3}{8}$ " wall thickness.

^f 6 mi. 0.178 wall thickness and 12 mi. 0.280 wall thickness.

* Exclusive of two 6600 ft. lengths installed in Narrows and two 290 ft. circuits.

^b No manholes. Splices average 1600 ft. apart.

^c Only one manhole between ends. Splices average 1400 ft. apart.

^d Generator leads only. No manholes between ends.

Cable Joint Pipe Sleeve Coatings

Of 15 utilities reporting how they coat the cable-joint pipe sleeves, 8 use paint, one of these first sandblasts and sprays on 8 mils of zinc. Paints used are Sipes Subway Black No. 96, Amercoat No. 33 (Vinyl), Glyptal, and asphaltic primer. Three utilities apply Somastic, one of these by hand-troweling,

and the other 2 use molds. One of the utilities using paint has also covered several sleeves with molded Somastic and is further testing them.

Two of the utilities using enamel coatings apply on the cable-joint pipe sleeves the same coating as is applied to the field welds.

One of the utilities uses two non-registering layers

TABLE 2—B. Pipe Coating

- 1 What type of external pipe coating is used?
- 2 What is softening point of electric insulating medium used in the pipe coating (asphalt, coal-tar, etc.)?
- 3 What is the nature of the primer coat and how is it applied?
- 4 What nominal and minimum thicknesses of the pipe coating do you now consider acceptable?
- 5 Is a protective outer surfacing applied to the pipe coating? If so, what type is used?
- 6 What method is used for applying coating over field pipe welds? Is primer used?

Company	Question B-1	Question B-2	Question B-3	Question B-4		Question B-5	Question B-6
				Nominal Thickness	Minimum Acceptable Thickness		
A	Somastic Type 2	Melting point (Ball and ring) 210 F. minimum	Primer is asphalt in petroleum thinner applied by spraying to cleaned metal	$\frac{1}{2}$ "	$\frac{3}{8}$ "	Yes. Whitewash	(See A-B-6 below)
B	Somastic	Melting point (Ball and ring) 210 F.	A natural or mfg'd. asphalt thinned with a petroleum thinner (white gasoline). (See B-B-3 below).	$\frac{1}{2}$ "	$\frac{3}{8}$ "	Yes. Whitewash	(See B-B-6 below)
C	Somastic	Exact value not known. Believed 150 to 210 F.	Somastic primer	$\frac{1}{2}$ "		Yes. Whitewash	Welds are painted with Primer then hot coating material in a mold.
D	Somastic	Melting point (Ball and ring) 210 F. minimum	Somastic primer	$\frac{1}{8}$ "	$\frac{1}{2}$ "	Yes. Whitewash	Molds—Primer is used
E	Somastic	150 F.	Somastic primer applied cold	$\frac{1}{2}$ "	$\frac{3}{8}$ "	Yes. Whitewash	Molds—Primer is used
F	Somastic	(See F-B-2 below)	Primer is asphalt in an appropriate petroleum thinner. (.6 gallon per 100 sq. ft. minimum)	$\frac{1}{8}$ "	$\frac{3}{8}$ "	Yes. Whitewash	(See F-B-6 below)
G	Somastic	Does not have this information	Somastic primer applied with brush.	$\frac{1}{2}$ "	(See G-B-4 below)	No	Molds—Primer is used
H	Somastic	Not reported	Not reported	$\frac{1}{2}$ "	$\frac{1}{2}$ "	No	Molds—No primer used
I	Somastic	Asphalt	Somastic primer applied cold with brush.	$\frac{1}{8}$ "	$\frac{1}{8}$ "	No	Molds filled and tamped with hot Somastic, closed allowed to cool. Primer used
J	Barrett's Special Waterworks Enamel (See J-B-1 below)	(See J-B-2 below)	Coal-tar cutback, rug-applied at pipe-wrapping mill.		0.156"	No.	(See J-B-6 below)
K	Somastic	Not reported	Liquid asphaltic material painted on.	$\frac{1}{2}$ "	$\frac{1}{2}$ "	Yes. Talc	Molds—Primer is used
L	Somastic	Melting point 175-200 F.	Mfg'd. asphalt, natural asphalt and appropriate thinner, applied hot.	$\frac{1}{8}$ "	$\frac{3}{8}$ "	Yes. Whitewash	Molds—Primer is used
M	No. 70B Bitumastic Enamel	Thoroughly liquid at 425 F.	Bitumastic primer applied with brush.	$\frac{3}{8}$ "	$\frac{1}{4}$ "	Johns-Manville tar-saturated pipe-line felt	Brush and sling—Primer is used
N	Somastic (See N-B-1 below)	Melting point 210 F.	Asphalt with thinner, applied by machine spray	$\frac{1}{2}$ "	$\frac{3}{8}$ "	(See N-B-5 below)	Molds—Primer is used
O	Somastic	Not reported	Not reported	$\frac{1}{8}$ "		(Not reported)	Molds.
P	(See P-B-1 below)	Not reported	Red lead on unburied pipe			No	Bitumastic and felt applied. No primer used
Q	Somastic	180 F.	Somastic primer applied by spray	$\frac{1}{8}$ "	$\frac{3}{8}$ "	Yes. Whitewash	Molds—Primer is used

J-B-1. 2 spiral wraps of 15# per square of coal-tar impregnated pipe line asbestos felt.

N-B-1. With Herculite (concrete) on river crossings.

P-B-1. Boone—Bedford Grey Enamel; Kentucky—Bitumastic Enamel; Wilson Dam—Somastic Coating.

F-B-2. (a) Penetration at 77 F, 25-27 mm (ASTM D5-25).

(b) Melting point (ball and ring) 160 F minimum (ASTM D36-26).

(c) Ductility at 77 F, 4.5 cm (ASTM D113-44).

J-B-2. Special plasticized coal-tar, softening point 235 F.

B-B-3. The primer coat can be sprayed or brushed on, depending upon conditions at time of application.

G-B-4. Thickness less than $\frac{1}{2}$ " acceptable if it passes Holiday Detector set for $\frac{1}{2}$ " coating.

N-B-5. On River crossings only: $1\frac{1}{2}$ " of concrete reinforced with #18 gage chicken wire.

A-B-6. Pipe metal is cleaned by wire-brushing. Asphalt primer is brush-applied. Hand form mounted on pipe, filled with hot mastic, closed and later removed when mastic has set.

B-B-6. Hot Somastic is poured into mold and puddled to remove trapped gases in mold. Mold is clamped shut and allowed to cool. Primer is used.

F-B-6. Pipe is cleaned by wire-brushing, the surface of pipe is heated with propane torch until pipe is hot to touch, asphalt primer is heated to 150 F and brush-applied. Hand mold mounted on pipe, filled with hot mastic, closed and removed later.

of 4-inch Orco tape with Roybond Adhesive A-99 as primer and between tape layers. One utility reports unsuccessful use of tape and is studying other methods.

Moisture Conditions in Manholes

Moisture conditions of joints in manholes are: Nine of 15 utilities report joints in manholes are 100 per-

cent dry or preponderately dry. Two utilities report 75 percent occasionally submerged, with the remainder dry in one case and continuously submerged in the other. One utility reports 50 percent dry and 50 percent occasionally submerged. One utility reports 60 percent dry, 27 percent occasionally submerged and 13 percent continuously submerged. One utility

7 What, if any, provision is made to remove moisture from ends of original coating adjacent to pipe welds when coating is applied over welds?

8 If a mold is used to apply coating to pipe, what treatment is used to prevent the coating from sticking to the mold?

9 How are cable-joint pipe sleeves coated?

10 If in manholes, what proportion of the joints are: a. Dry %? b. Occasionally submerged %? c. Continuously submerged %?

11 Where trench is backfilled with other than the originally excavated material, what type of backfill is used?

Question B-7	Question B-8	Question B-9	Question B-10			Question B-11
			a. Dry Percent	b. Occasionally Submerged Percent	c. Continuously Submerged Percent	
Whitewash is wire-brushed from pipe coating to assure good bond. Excavation is kept dry by pumping, if necessary. In unusual cases, coating may be dried by flame from torch.	Inside surface of mold is painted with whitewash prior to use.	Manhole piping and sleeves painted with Sipes Subway Black No. 96.	95	0	5	Clean sand.
(See B-B-7 below.)	(See B-B-8 below.)	(See B-B-9 below.)	80	3	17	The pipe is surrounded by 6 inches of sand.
Moisture is removed from these faces by heat, a torch flame.	Vegetable oil on the mold surfaces.	(See C-B-9 below.)	10	10	80	Excavated earth is returned to the trench except under street pavement where sand is used.
Somastic applied at 350 F.	(See D-B-8 below.)	Paint.	97.5	0	2.5	Sand.
Surface is cleaned with a wire-brush and dried with a torch.	A whitewash is applied to the inner surface of the mold.	All cable-joint pipe sleeves are in relatively dry manholes and are not coated.	100	0	0	(See E-B-11 below).
Ends of coating and pipe surfaces are wire-brushed, heated with a torch, and then given a heavy coat of primer.	Inside surface of mold is painted with whitewash prior to use.	The cable-joint pipe sleeves are sand-blasted, zinc-sprayed 8 mils thick, and two coats Amercoat No. 33 (Vinyl).	60	27	13	Clean sand.
None.	Whitewash.	Hand-troweled with Somastic.	25	75	0	(See G-B-11 below).
None.	Whitewash.	Tried taping unsuccessfully; now studying other methods.	0	75	25	No. 9 grits.
Most molding is done after welding—Somastic hot and dry. Other cases, all free water is removed by gas torch.	Whitewash.	Same as weld joints with partial mold.	No permanent manholes			6-inch sand bed and covered with 6 inches of sand
No special provision other than to keep trench dry.	(Does not use mold.)	Same as field welds (wrapped with enamel and felt applied, using primer).	No manholes			River sand (fine grade alluvial deposit).
Moisture removed as a result of heating Somastic to make it pliable.	Inside of mold painted with kerosene.	With molds.	100	0	0	Black dirt, or sand.
Moisture removed by light "torching" of area concerned.	Whitewash.	Painted with priming coat and finished with corrosion-resisting paint.	50	50	0	About 3 to 6 inches of rock-free loam around pipe.
None.	(Does not use mold).	Same as field welds (enamel applied with brush and sling, using primer).	80	10	10	Clay pack.
None.	Whitewash on mold interior.	(See N-B-9 below.)	40	38	22	Builders sand for first 12 inches; any clean fill thereafter.
(Not reported.)	(Not reported.)	Painted with Glyptal.	85	10	5	Sifted earth.
(Not reported.)	(Does not use mold.)	Short generator leads only, no cable joints.	100	0	0	Embedded in sand before back-filling with excavated material.
Heated with blow torch.	Whitewash.	Painted with asphaltic primer.	100	0	0	Screened loam to 1 ft. above pipe, remainder sand backfilled.

J-B-6. Joints are wrapped cigarette-fashion, using Waterworks-type enamel, two thicknesses of asbestos pipe-line felt, 15#/square. Primer is used.

B-B-7. The pipe ends are wire-brushed to remove any foreign material which might have adhered to pipe and coating during installation. The ends of the Somastic are further cleaned by heating and troweling to remove loose Somastic and any remaining foreign matter.

B-B-8. A vegetable oil is used to coat the mold contact surfaces. The oil is soya bean oil.

D-B-8. Molds are only used when coating field joints. Inside of molds are coated with whitewash.

B-B-9. The sleeve is cleaned and painted with a black nitros paint. Several sleeves have been covered by a molded Somastic covering and at this time are being further tested.

C-B-9. All cable-joint pipe sleeves are in manholes and are covered with Sipes Subway Black No. 96 paint brushed on.

N-B-9. Roybond Adhesive A-99 primer; one layer of 4" Orco tape, butt-wrapped; one layer Roybond Adhesive A-99; one layer of 4" Orco tape, non-registering butt-wrapped.

E-B-11. Soil similar to that removed from trench and sifted through ½-inch mesh screen, if necessary, to remove foreign matter.

G-B-11. Sand or sandy material. After backfill, a 3-inch pad of red concrete is installed 6 inches above the pipe.

TABLE 3—C. Holiday Detection

C. HOLIDAY DETECTION

- 1 What type and make of holiday detector is used on pipe coating before pipe is buried?
- 2 What voltage is applied? Is this voltage RMS or peak?
- 3 What is the size and type of electrode for applying test voltage to coating?
- 4 When are holiday detector tests made?

- 5 What method is used to locate the exact points of failure of pipe coating after the pipe has been buried?
- 5-a Shortly after burying (before line is placed in service)?
- 5-b-1 After a considerable time?
- 5-b-2 Can this be accomplished while the cable is in operation?

Company	Question C-1	Question C-2	Question C-3	Question C-4	Question C-5a	Question C-5b-1	Question C-5b-2
A	(See A-C-1 below).	18,000 volts. Peak.	1/4-inch copper tubing bent to curvature of the pipe and covering approx. one-third of the circumference of coated pipe.	At coating plant (by coating contractor) and after pipe is installed in trench (by our own testers).	Over-the-ground potential gradient survey with interrupted direct current applied to insulated pipe.	Same 5-a.	No.
B	(See B-C-1 below).	20,000 volts or 3/4-inch spark gap. RMS.	(See B-C-3 below).	(See B-C-4 below).	(See B-C-5a below).	(See B-C-5b below).	To date no Somastic testing has been done while cables are energized but it is contemplated in the near future.
C	High voltage—with storage battery, interrupter, spark coil, and a wire-brush-type collar.	Voltage is controlled by a 0.75-inch spark gap. Actual volts, RMS or peak, is not known.	Flexible wire-brush type collar fitted around the pipe in contact with coating for about 2" of pipe length. A curved wire brush is used to test patchwork.	At coating plant and over the trench just before pipe is lowered into the trench.	(See C-C-5a below).	No. Not repeated after pipe-line installation was completed.	Appears possible but rather complicated and with limitations.
D	H. C. Price Co. Model A (Storage battery, interrupter, spark coil.)	24,000 volts. Peak.	Ring-spring.	At coating plant and just before lowering pipe into trench. Repairs are also checked.	Pearson holiday detector Type A.	(Not reported.)	(Not reported.)
E	A spark coil.	30,000 volts. Peak.	Circular steel wire brush having bristles approx. 3' long. Inside diameter of brush slightly smaller than outside dia. of coated pipe.	Upon receipt of pipe, before lowering into trench and immediately before backfilling over the pipe.	By applying interrupted d. c. to pipe and checking the flow of current in the earth with measurements at spaced intervals over the pipe-line with a high resistance (See E-C-5a below).	Same as 5-a.	No.
F	High voltage spark-type detector with a 3/4-inch gap limiter.	26,000 volts. Approx. (3/4-inch gap). Peak.	Split circle brush with a single row of copper bristles constructed to fit the outside diameter of the coating.	Immediately after application of coating and again before pipe is lowered into trench.	Over-the-ground potential gradient survey with interrupted direct current applied to insulated pipe.	Same as 5-a.	No.
G	Whatever type recommended and furnished by cable manufacturer.	30,000 volts approx. Peak.	Wire brush of diameter slightly less than O.D. of Somastic.	Usually with pipe in position above ditch. In some cases after pipe is in trench.	Interrupted voltage applied to pipe. Pinhole survey conducted, using vacuum tube voltmeter and CuSO ₄ electrodes. Potential difference between electrodes. (See G-C-5a below).	Have not found it necessary to locate pinholes after line is placed in service.	Coating fault would be located with cable in operation, but probably would interrupt service from safety standpoint.†
H	Made by cable manufacturer.	30,000 volts. Peak.	Metal "cat whiskers" fastened to a split ring.	Just before lowering pipe into trench.	Applied 90-cycle voltage to pipe and used probes on paving or ground above pipe very successful.	Same as 5-a.	Have not tried.
I	Stearns electronic holiday detector and Detroit Coil (made locally).	25,000 volts. Peak.	Ring-spring. Also circular cat-whisker brush for patchwork.	Before bringing on job and before lowering into trench.	18-volt battery automatically interrupted between pipe and ground with search made by one fixed electrode and one searching electrode connected to vacuum tube. (See I-C-5a below).	Same as 5-a.	No.
J	Stearns electronic holiday detector.	15,000 volts. RMS.	Ring-spring.	At wrapping mill and also just before lowering into trench.	Right after burial, using two CuSO ₄ electrodes, battery and interrupter, with vacuum tube voltmeter.	Same as 5-a.	Yes, but not necessary since pipe is cathodically protected.
K	H. C. Price Co. spark-gap type.	30,000 volts. Peak.	Hook-shaped electrode, 4" handle and approx. 7" radius hook.	Just prior to installing pipes, and after any excavated exposures.	D-c voltage earth gradient method.	No coating failures as yet. Would probably use method of 5-a.	Yes.
L	Spark-coil type, purchased from Bechtel Corp. (Los Angeles, Cal.)	Order of 20,000 to 40,000 volts. Peak.	Typical wire-brush type.	Before backfilling.	Specially developed d-c circuit, using a potentiometer voltmeter.	Same as 5-a when failures are indicated.	No.
M	None.	None.	None.	None.	None.	After pipe failure—oil seeping from ground.	Yes.
N	H. C. Price Co. Model A.	30,000 volts. Peak.	Split ring on centering rollers, with radial flat wire bristles.	Over the trench just before lowering into trench.	Pearson fault locator or variation thereof where no interference from overhead lines or neon signs. Voltage gradient at 40-ft. intervals using current to anode.	Same as 5-a.	Yes.
O	Holiday detector furnished by Somastic pipe coating contractor.	(Not reported.)	Circular wire brush of diameter about 1/4" less than O.D. of coating.	Just before lowering into trench.	(Not reported.)	(Not reported.)	No.
P	(Not reported.)				(Not reported.)	(Not reported.)	(Not reported.)
Q	Stearns electronic holiday detector.	30,000 volts. Peak.	Ring-spring. Also circular brush electrode.	Before lowering into trench and on completed joints in trench. On curves, tested again before backfilling. Tests also made after leaks were repaired.	Tracer current and pick-up coil.	Same as 5-a. Plus d-c current leakage along pipe.	Yes.

reports 40 percent dry, 38 percent occasionally submerged, and 22 percent continuously submerged. One utility reports 80 percent continuously submerged.

Backfill

Where trench is backfilled with other than the originally excavated material, the following types of backfill are used.

Ten of 17 utilities use sand or clean sand. Three of these cover the pipe to a depth of 6 inches, one then covering the sand with a 3-inch pad of red concrete. One of the 10 using sand covers the pipe with sand for first 12 inches then with clean fill.

Two utilities use screened loam, one to a depth of one foot over pipe with remainder sand, and the other about 3 to 6 inches around pipe.

One utility uses excavated earth sifted through $\frac{1}{2}$ -inch screen, one uses sifted earth, one No. 9 grits, one uses a clay pack and one backfills with excavated earth except under street paving where sand is used.

C. Holiday Detection

Of 15 utilities reporting they use holiday detectors on the pipe coating before burying the pipe, 12 use a high-voltage spark coil operated from a storage battery with vibrator or motor-driven interrupter. The other 3 use the Stearns electronic holiday detector, a pulse generator applying high voltage pulses at the rate of 30 pulses per second.

Voltagcs Used

Among 15 utilities making coating tests with holi-

day detectors, 11 report applying peak voltages ranging from 18,000 volts to 40,000 volts, with 6 utilities reporting use of 30,000 volts peak. One utility reports using 15,000 volts RMS. Three utilities report using a $\frac{3}{4}$ -inch gap limiter.

Types of Electrodes

For the 15 utilities reporting use of holiday detectors, the sizes and types of electrodes for applying the test voltage to the coating are as follows.

Ten utilities use a split annular brush, with one of them also reporting use of a 6-inch brush to test patchwork. Bristles were reported of copper or steel 2 to 3 inches long. Four utilities use a ring-spring, 2 of these also using an annular brush electrode. One utility uses a bent $\frac{1}{4}$ -inch copper tube covering approximately $\frac{1}{3}$ pipe circumference. One utility uses a hook-shaped electrode of 7-inch radius.

When Coating Is Tested

The times of making holiday detector tests were reported as follows.

Of 15 utilities reporting holiday testing before burying the pipe, 12 make these tests just before lowering the pipe into the trench, with 7 of these also testing at the coating plant or storage yard and one of the latter additionally testing after lowering the pipe into the trench. One utility tests at the coating plant and after the pipe is lowered into the trench. One utility usually tests just before lowering the pipe into the trench, but in some cases after the pipe is in the trench. One utility tests only after the pipe is lowered into the trench. Three utilities report also testing after repairs to coating and one also tests for holidays after any excavated exposures.

Locating Holidays

The methods used to locate the exact points of failure of the pipe coating after burying and before the cable is placed in service, are:

Of the 15 utilities reporting, 9 make surveys of over-the-ground potential to remote earth, using suitable electrodes, with interrupted direct current applied between the insulated pipe and ground. One of these 9 utilities also uses a 1000-cps signal and earphones, where interference makes the interrupted d-c method unsatisfactory. Two utilities use a Pearson holiday detector (1000-cps signal applied between the pipe and a ground rod is picked up over the pipe, reinforced by electronic amplification and detected by headphones). One utility uses 90-cycle voltage on pipe, using probes over pipe on ground or paving. One utility uses a meter. One utility uses a tracer current and pick-up coil. One utility makes no tests of the coating after the pipe is buried and before placing the line in service.

Of 12 utilities reporting method of locating exact points of failure of pipe coating a considerable time after the pipe has been buried, 11 use the same method as is used shortly after burying the pipe. Two of these 11 utilities also make tests of dc leakage current flow along pipe. One utility relies on oil seeping from ground to locate failure of coating (and pipe). Two utilities do not test for holidays after the line is placed in service.

FOOTNOTES FOR TABLE 3

- A-C-1. We use our own design and make consisting of 6-volt storage battery, motor-driven interrupter, extra heavy duty spark coil and condenser.
- B-C-1. A spark coil having a 6-volt storage battery as a power source is used as the source of high voltage. The magnitude of the high voltage is limited by an adjustable shunt air gap. This gap is set such that a $\frac{3}{4}$ -inch spark length is available at the test electrode.
- B-C-3. Two types of electrodes are used to test pipe coating. The first, a split circular brush, is capable of testing all or half of the pipe circumference, depending upon whether all or half of the brush is used. The second, a 6-inch brush, is used to test patchwork. Both brushes have flexible wire hair approximately 2-3 inches long which contact pipe coating surface.
- B-C-4. (a) Factory tested-sample checking. (b) Storage Yard. (c) Final check just previous to installation in trench. (d) Any time Somatic is damaged or broken and repaired.
- B-C-5a. An interrupted d-c voltage is impressed on the faulty section. A vacuum tube voltmeter is used to measure the voltage drop between a ground rod remote to the pipe and a copper-copper sulfate half cell. The half cell is located in the tip of a cane. The half cell is moved along the center line of the pipe until the greatest swing is noted on the voltmeter. The remote ground is then moved adjacent to the indicated fault and the cane again moved until a peak deflection is indicated. By varying the distance between the pipe and remote ground rod quite accurate fault determinations can be attained. A 1000-cps signal and earphones are used where interference makes the interrupted d-c method unsatisfactory.
- C-C-5a. A pulse potential of 200 to 250 volts d.c. is applied to pipe, and earth over pipe is explored for pulsing potential. This is done after pipe sections are backfilled and puddled and settled as long as possible while still able to test sections.
- E-C-5a. (Cont'd) millivoltmeter connected to suitable electrodes.
- G-C-5a. (Cont'd) measured every 10-15 ft on sections of pipe which do not meet minimum coating resistance standard of 10 megohms per sq ft.
- I-C-5a. (Cont'd) voltmeter (100-mv scale).
- B-C-5b. A section of pipe adjacent to each manhole is used as a calibrated shunt. Two insulated leads are attached to the pipe, one inside the manhole and the other 50 or 80 ft from the manhole wall. The following test is used to determine the leakage or resistance per section and overall resistance. A d-c voltage is impressed on the ungrounded pipe (negative) and the total leakage current held constant. Source voltage and current readings are recorded while another group takes millivolt readings at each of the shunts. The overall resistance and the magnitude of the leakage current at each shunt can be calculated from the above mentioned data. Faulty sections are located in this manner. The test described in question 5-a is used to further locate the fault so that the fault can be repaired.

Of 14 utilities reporting whether or not tests for location of exact points of pipe coating failure can be made while the cable is in operation, 7 do not test for holidays while the cable is operating. Five utilities report their tests can be made while the cable is in operation. One utility reports such tests are

contemplated in the near future, one states such tests appear possible but seem complicated and have limitations.

D. Coating Resistance Measurements

Fifteen utilities reported methods used by them to

TABLE 4—Coating Resistance Measurements

D. COATING RESISTANCE MEASUREMENTS

- 1 What method is used to make initial measurements of coating resistance?
- 2 On initial measurements of coating resistance, what lengths of pipeline are individually measured?

3 How soon after burying pipe are initial measurements of coating resistance made?

4 Is buried pipe "puddled" (backfill saturated with water) before making initial tests of coating resistance?

7-b How frequently are such measurements made?

Company	Question D-1	Question D-2	Question D-3	Question D-4	Question D-7-b
A	Battery and voltmeter method for high resistance measurements. Voltmeter and ammeter method for low resistance measurements.	(See A-D-2 below.)	On progressively increasing lengths of pipe until section is completed and backfilled.	No.	If possible, annually.
B	(See B-D-1 below.)	Each section between manholes is checked separately.	Each section is tested after backfilling is complete.	No.	Six to twelve months.
C	For lengths between manholes—voltmeter, ammeter with 200 to 250 volts d.c., also 500-volt megger.	1400—1500 ft.	Within a week, depending on length of time pipe sections are isolated.	Yes.	Only once to date but believe annual measurements desirable.
D	(See D-D-1 below.)	Manhole to manhole sections.	As soon as possible.	Yes.	Annually.
E	Voltmeter-ammeter method at 100 volts, d.c.	Approximately 2500 ft.	As soon as possible.	No.	Semi-annually.
F	Battery, voltmeter, and ammeter method.	Manhole to manhole measurements.	Immediately following installation.	Yes.	Every two to three years.
G	(See G-D-1 below.)	Individual sections between manholes.	Varies, depending on length of line and construction schedule.	No. (Only when faults are located and repaired.)	.....
H	22-volt battery and a milliammeter.	Between manholes.	(Not reported.)	No.	.....
I	A potential and current flow was placed on the isolated pipe section; total resistance was determined by change in voltage divided by change in current.	Tests were made on pipe sections before splicing (approximately 2000-ft. sections).	As soon as possible.	No.	Annually.
J	Measurement of delta voltage with corresponding current measurement.	Measured right after pipe sections laid. Individual sections averaged roughly 1600-ft. length. Max. length 2500 ft.	Immediately.	Not normally necessary as ground water table is high.	.....
K	Megger.	No definite lengths.	Approximately one week.	No.	Three times daily. (Monitoring of cathodic protection system.)
L	Ammeter-voltmeter method using 90 volts d.c. and Ohm's Law.	Sections between manholes, of the order of from 800 to 1500 ft. in length.	Within a few days after backfilling.	Yes.	Annually.
M	None.	.....	.....	.....	.....
N	Measure the change in pipe-to-ground voltage due to a current increment.	Manhole to manhole sections (approximately 2200 ft.).	Less than one week. However, measurements are not considered final until the backfill is saturated.	No.	Once a year.
O	D-c resistance calculated from measurements of d-c voltage and leakage currents.	On completed cable sections.	After cable has been pulled into pipe and all splicing operations have been completed.	Yes. In most cases.	Two times a year.
P	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)
Q	A special ohmmeter with a 45-volt battery. Readings were taken with reversed polarity and at various voltages.	The spans between manholes—approximately 1700 ft.	Immediately after each pipe span was installed.	No.	Once a year.

B-D-1. A 500-volt megger is used in most cases. Where the megger reading proves unsatisfactory, d-c potential is applied to the pipe and the current and voltage read. A series of B-batteries or a motor-generator set are used as sources of potential.

D-D-1. Direct current voltage applied between pipe conduit and convenient ground. Measure current flow caused by d-c voltage and potential of pipe conduit with respect to soil. Resistance of pipe coating is change in pipe-to-soil potential divided by change in current.

G-D-1. Interrupted voltage applied between pipe and ground. Resistance calculated from off-on voltage difference measured on HR voltmeter to CuSO_4 electrode and off-on current difference.

A-D-2. Coating resistance tests are made during installation on pro-

gressively increasing lengths of pipe until section between manholes is completed and backfilled.

B-D-5. A resistance value of 10 megohms per sq ft is the goal set. Several lines fall below this value because of faults which have not as yet been repaired.

F-D-5. Acceptance based on holiday detection tests, 30 megohms per sq ft usually obtained. No minimum is specified. The highest value obtainable without the excessive cost involving replacement of the coating on entire lengths of pipe is accepted. If coating is found to be poor, cathodic protection would be cheaper than replacing it, and therefore would probably be applied.

A-D-7a. After feeder is removed from service, ground connections are temporarily removed from pipe. Battery potential is applied

make initial measurements of coating resistance. Eight use voltmeter-and-ammeter method with dc voltage applied, two of these also using a 500-volt megger and one using a battery-and-voltmeter for high resistance measurements. Five utilities determine coating resistance from change in pipe-to-

ground voltage due to current increment. One utility uses a megger and another uses a special ohmmeter with a 45-volt battery, with readings taken at various voltages and reversed polarity.

Of the 15 utilities reporting they make initial measurements of coating resistance, 14 make these

5 What is minimum resistance (megohms/sq ft of pipe area) acceptable on initial test of coating?

6 What was initial average resistance of pipe coating for each line? (Megohms/sq ft pipe area.)

7-a What method is used to make measurements of coating resistance of the pipe after line has been placed in operation?

7-c Are such measurements regularly scheduled?

7-d Are such measurements made on less than terminal-to-terminal lengths?

8 Can you indicate rate of depreciation of average resistance of pipe coating (for example, by giving annual values)?

Question D-5	Question D-6							Question D-7a	Question D-7-c	Question D-7-d	Question D-8
	I	II	III	IV	V	VI	VII				
12.5	21.7 to 30.7	0.75 to 30.0	5.0 to 44	15.9 to 27.0	30.6 to 54.6			(See A-D-7a below.)	Yes.	Yes.	Our tests show that coating resistance decreased tenfold in 2½ years.
(See B-D-5 below.)	9.3*	9.70*	9.70*	4.37*	3.96*	13.6*	10.5*	The procedure followed is the same as mentioned in C-5-a and C-5-b (1) after line has been de-energized.	No regular schedule has been laid out as yet but it is contemplated in the future.	No.	Not sufficient data available.
10. For long section coating can be broken and still be above this figure.	Over 100**	Over 100**						Voltmeter-ammeter with low voltage d.c. as tests were made to determine requirements for cathodic protection.	Not as yet.	No. Will not be able to sectionalize the lines.	No.
5	No values obtainable for entire lines.							Only line No. 1 has been in service long enough for periodic tests. Same method employed as D-1 with cable removed from service.	Yes.	No.	The values are inconsistent.
10	5.0	10.7	8.0					Same as D-1.	Yes.	Yes.	Insufficient data to date.
(See F-D-5 below.)	89.0	30.1	21.9	34.5	24.3	17.5	2.6	(See F-D-7a below.)	No. Made when it is practicable to obtain interruption.	Yes.	Our tests show that coating resistance dropped from 1/10 to 1/35 the original value in 2 years and then to about 1/125 the original value in 6 years.
10	25.0	9.85	Not Completed		No record			(See G-D-7a below.)			No.
(Not reported.)	(Not reported.)							None.	No.		No.
10	992 (Max.) 1.5 (Min.)	8.6 (Max.) 0.4 (Min.)	Still Under Constr.					Line taken out of service and tests made as D-1.	Yes.	No.	No indication at this date.
0.104	1.321							None.			No.
10	Approx. 12							From the voltage and current of the cathodic protection system.	Yes.	No.	No noticeable change.
No data		192						Same as D-1.	Yes.	No.	No. We plan trying to arrive at some method to evaluate the rate of depreciation.
								None.			
10	5.7							Same as D-1. (Ground voltage shift.)	Will be.	No.	Insufficient experience.
1.5	2.82							Same as D-1. (D-c resistance measurement.)	Yes.	Yes.	(See O-D-8 below.)
(Not reported.)	(Not reported.)							(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)
5.4	47.63							Line de-energized and pipe grounding removed; then resistance to earth measured.	Yes.	No.	No estimate made as yet.

between insulated pipe and the station ground, and the current flow measured. Current flow on pipe is measured at an intermediate point on pipe. Thus each pipe in effect is divided into two portions, and the coating resistance determined for each portion. Resistance is calculated from pipe potential and current.

F-D-7a. After feeder is removed from service, ground connections are temporarily removed from pipe. Battery potential is applied between insulated pipe and the station ground and the current flow measured. Current flow on pipe is measured at an intermediate point on pipe. Thus each pipe in effect is divided into two portions, and the coating resistance determined for each portion. Resistance is calculated from pipe potential and current.

G-D-7a. Coating resistance not measured after line is placed in operation. Depend on periodic voltage and current measurements on pipe to indicate coating failure if values differ appreciably from previous measurements.

O-D-8. Change in Leakage Resistance (initial resistance 2.82 megohms/sq ft): 4-13-49—1.07 megohms/sq ft; 10-14-49—0.427 megohms/sq ft; 3-28-50—0.306 megohms/sq ft; 10-10-50—0.225 megohms/sq ft; 11-4-52—0.212 megohms/sq ft.

* The initial average resistances listed are the values of coating resistance at time line was placed in service. The majority of the faults had been located and repaired.

** These tests did not include the single-conductor pipes leading to the end terminating structures—the coating of these pipes resulted in a much lower resistance.

measurements on manhole-to-manhole sections of pipeline, one of these also making them on increasing lengths of pipe until the section is completed. One utility reports no definite lengths of pipe are tested.

Of 14 utilities reporting how soon after burying the pipe initial measurements of coating resistance are made, 7 make these measurements as soon as possible after installation. Four utilities make these measurements within a week following installation, and one of these does not consider measurements

final until the backfill is saturated. One utility makes measurements on increasing lengths of pipe until section is completed and backfilled. One utility makes these measurements after all cable splicing is completed. One utility reports time of such measurements varies, depending on length of line and construction schedule.

Puddling Backfill

Of 15 utilities reporting whether the buried pipe is

TABLE 5—E. Grounding Provisions and Drainage Bonds

E. GROUNDING PROVISIONS

- 1 Is pipe grounded at terminals? If so, by what means?
- 2 If pipe is not directly grounded at terminals, what provision is made for fault current return?
- 3 Is pipe grounded in manholes? If so, by what means?
- 4 Is pipe grounded to other structures en route?

F. DRAINAGE BONDS

- 1 Are drainage bonds used?
- 2 Up to what approximate magnitude of current are such bonds designed to drain?

Company	Question E-1	Question E-2	Question E-3	Question E-4	Question F-1	Question F-2
A	(See A-E-1 below). Yes. Four parallel 1/0 rubber-insulated cables connect pipe to station ground mass at each of the line terminals.	(See A-E-2 below.)	No.	No.	None at present.	.....
B	.....	.....	No.	No.	No.	.....
C	Yes, when first installed. Now grounded at terminals through a low-voltage gap.	A low voltage gap in the grounding connection at each end of each line.	Not yet. Magnesium anodes are to be installed in each manhole to provide some grounding and cathodic protection.	No.	(See C-F-1 below).	Not designed on a current drainage basis.
D	Yes, through a 2-volt cell of station type lead-acid storage battery.	(See D-E-2 below.)	No.	No.	No.	.....
E	Yes. Solidly to station ground grid.	.....	Yes. Solidly to two 1" x 10' Copperweld ground rods.	No.	No.	.....
F	Yes. By equivalent 630,000 cir mil ground straps between pipe and station ground.	.....	Yes. 2/0 copper wire connected to pipe and driven ground rod.	Yes. Only where drainage bonds are required.	Yes.	(See F-F-2 below.)
G	(See G-E-1 below)	.....	No.	No.	No.	.....
H	No. Five high current gaps throughout length.	Pipe is insulated from ground, but has 5 high current gaps throughout its length—gaps break down at 400-600 volts.	No.	No.	No.	.....
I	Yes. Through station battery such that short-circuit current can be 10,000 amp. for 1 sec.	Battery size will carry fault currents.	No.	No.	No.	.....
J	Yes. Tied solidly to ground at generating stations (not solidly at substations).	.....	No manholes.	Yes, to galvanic anodes and through resistance bond to common neutral.	Yes.	50-100 amp of stray railway current.
K	Yes. At one terminal only. Through the cathodic protection cell to an isolated ground.	.....	No.	No.	No.	.....
L	Yes. By means of a removable ground wire secured to a ring which has been welded to pipe. Pipe is otherwise isolated from ground.	.....	No.	No.	No.	.....
M	No.	None.	No.	No.	Yes.	180 amp.
N	Yes. Grounded to station ground through 3000-mfd capacitors to limit a-c voltages at each end.	Cu-CuO rectifier discs placed face-to-face connected from pipe to ground for fault current-breakdown 35-50 volts.	Yes. Magnesium anodes.	No.	No.	.....
O	Yes. Flexible connector from spreader frame to steel structure and sub-station ground.	.....	No.	No.	No.	.....
P	Yes. Ky—At switchyard end pipe is fastened to steel H frame member for support. Bonded (See P-E-1 below.)	.....	(Not reported.)	No.	(Not reported.)	(Not reported.)
Q	Yes. Through expendable rectifiers, adjustable air gap and low-volt neon bulbs.	Through expendable rectifiers, adjustable air gap and low-volt neon bulbs.	No.	No.	No.	.....

E-E-1. Yes. By 500,000 cir mil copper cable connected between each pipe and station ground. In many installations a 2-volt storage cell is connected in series with the ground cable so as to maintain pipe potential negative with respect to the earth.

G-E-1. Yes. Installations I through IV grounded directly at one terminal and through cathodic protection system (2-volt battery and rectifier) at other terminal. Installations V and VI grounded directly at one terminal only without cathodic protection.

P-E-1. (Cont'd) at generator end. Wilson-Bonded at one end.

A-E-2. Where pipe cable is joined to lead sheath cables in ducts an insulating joint is provided in the lead sheath cables. The insulating joints are bonded across with 4/0 bonds at all times except when measurements are made of coating resistance.

D-E-2. The lead-acid storage battery has been tested and has withstood three tests at a nominal current of 10,000 amp a.c. for one sec, and one test at 15,000 amp for one sec.

C-F-1. No, except perhaps as indicated above (contemplate installing magnesium anodes in each manhole).

F-F-2. Primary consideration in the design of drainage bonds is voltage change of pipe with respect to adjacent earth. Current is considered only when other structures are involved or voltage changes obtained are excessive. Present bonds carry up to about 50 amp.

"puddled" (backfill saturated with water), before making initial tests of coating resistance, 10 do not puddle the pipe; one of these reporting this is not normally necessary as water table is high and another reports puddling of pipe after coating repairs. Five utilities report they puddle the pipe before making these tests.

Minimum Resistance

Thirteen utilities reported values of minimum resistance (megohms/sq ft of pipe area) acceptable on initial tests of the coating. Seven of these give 10 megohms/sq ft as minimum acceptable resistance. Five other utilities report respective individual val-

ues of 0.104, 1.5, 5.0, 5.4, and 12.5 megohms/sq ft of pipe area, as the minimum acceptable. One utility finds 30 megohms/sq ft usually obtainable but specifies no minimum and accepts the highest value obtainable without replacing coating on entire lengths of pipe.

The initial average resistance of pipe coatings for individual circuits of 13 utilities ranged from 1.32 to over 100 megohms/sq ft of pipe area.

Methods used to make measurements of coating resistance of the pipe after the cable has been placed in operation, are as follows. Of 16 utilities reporting, 8 remove the cable from service, apply dc potential

TABLE 6—G. Stray Current Requirements

G. STRAY CURRENT MEASUREMENTS

1-a What provision is made for measurement of stray current along pipe?

1-b Are sections of pipe used as calibrated shunts for measuring stray currents?

1-c If so, what shunt resistance is used?

1-d At what intervals along the line are these shunts located?

2-a Are pipe-to-earth potentials measured? If so, how?

2-b Are potential measurements made to other structures?

3 Are stray current and potential surveys made on regular schedule? If so, how frequently?

Company	Question G-1-a	Question G-1-b	Question G-1-c	Question G-1-d	Question G-2-a	Question G-2-b	Question G-3
A	Shunt leads attached to pipe at points approximately 80 ft. apart and terminated in manholes.	Yes.	Approximately 0.001 ohm.	At each manhole.	Yes. Potential difference measured with 400,000-ohm voltmeter connected between pipe and clean steel probe driven into earth.	Yes. (e.g. water pipes, gas pipes, etc.)	Yes. Biennially.
B	A section of pipe adjacent to each manhole is used as a calibrated shunt.	Yes.	(See B-G-1-c below.)	At each manhole.	No.	Yes.	(See B-G-3 below.)
C	None special. Can use section of pipe between manholes if necessary.	Pipe not calibrated. Pipe resistance to be calibrated as needed.	To be calculated as needed—if needed.	See above. (Expects to use manhole-to-manhole length.)	Yes. CuSO ₄ electrode and high resistance meters.	None as yet—few to consider.	Yes. Once a year.
D	Calibrate sections of pipe.	Yes.	Approximately 80 ft. of pipe.	One per manhole section.	Yes. Buried zinc reference electrode.	Yes.	Yes. Annually.
E	Two potential leads spaced 50 ft.	Yes.	380 microhms.	At approximately 1/2-mile intervals.	Yes. With copper sulfate electrodes and a 200,000-ohm-per-volt voltmeter.	Yes.	Yes. semi-annually.
F	Shunt leads attached to pipe at points approximately 100 ft. apart and terminated in manholes.	Yes.	Approximately 0.001 ohm.	At each manhole.	(See F-G-2-a below.)	Yes.	No. (About every two to three years.)
G	Permanent test wires are installed on pipe between each manhole for I through IV. No provision for V and VI.	(See G-G-1-b below.)	Resistance varies because random lengths of pipe are used as shunts.	Between each manhole.	Yes. Potential measurements made on 24-hr. recording charts to zinc electrode buried below pipe.	No.	Yes. Every 6 months.
H	None.	No.			No.	No.	No.
I	Test stations (boxes) at approximately 1/2-mile intervals.	Yes. 100-ft. lengths.	100-ft. lengths calibrated with calibration indicated at test station.	Approximately 1/2-mile.	Yes. High resistance voltmeter and CuSO ₄ electrode.	Yes.	Yes. Monthly.
J	Use test leads provided for quarterly current and potential measurements.	Yes.	116-ft. length of pipe amp/mv/116-ft. = 1.0.	Roughly, 0.3 mile apart.	Yes. High resistance voltmeter, CuSO ₄ electrode.	Yes.	Yes. Quarterly.
K	Ground leads at 3 different points along the line.	No.			Yes. Ground leads connected to pipe terminate in nearby manhole (total of three).	Yes.	Yes. Annually.
L	None.	No.			Yes. Using CuSO ₄ electrode as reference to earth.	No.	Yes. Annually.
M	No special provisions. Use bond wire around joints in manholes.	No. Use 4/0 bond wire around joints in manholes.	One millivolt across one ft. of 4/0 bond wire represents 20 amp.	In every manhole. (4/0 bond wire around joint is used as shunt.)	Yes. High resistance voltmeter from pipe to copper ground rod driven in earth, or to steel rail.	Yes.	Yes. Semi-annually.
N	Insulated leads from a 40-ft. section of pipe are brought up to the mouth of each manhole.	Yes.	0.000445 ohm (2.25 amp/mv/40-ft.).	At each manhole (approx. 2,200 ft.).	Yes. (1) CuSO ₄ half cell; (2) Lead sheath of thermocouple which parallels pipe.	Yes.	Yes. Yearly.
O	None.	No.			(Not reported.)	No.	(Not reported.)
P	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)
Q	Two brazed copper lugs across 10 ft. of pipe including joint in each manhole for MV-drop measurements.	Yes.	10 ft. of pipe including joint in manhole.	Each manhole.	Yes. Measurements between pipe and earth with CuSO ₄ half cell.	Yes.	(Not reported.)

G-G-1b. Yes. But each section varies since test leads are installed only at joints and pipe is in random lengths. All lengths accurately measured for permanent record.

B-G-1c. 0.715 x 10⁻³ ohms per 80 ft. of 8-inch OD pipe; 0.612 x 10⁻³ ohms per 50 ft. of 7-inch OD pipe.

F-G-2a. A 10,000-ohm recording voltmeter is connected between the pipe and a lead plate in the wet manhole sump. The lead plate potential to a copper sulphate halfcell is then measured and the chart readings are corrected accordingly.

B-G-3. No regular schedule has been laid out as yet but it is planned for the future.

between pipe and ground and determine resistance from current flow and 3 of these also obtain sectionalized values from current readings at intermediate points. Three utilities determine the resistance from ground voltage shift due to current increments. Two utilities depend on periodic measurements of voltage and current of cathodic protection system. Three utilities report not making measurements of coating

resistance after the line is placed in service.

Periodicity of Resistance Measurements

For the 12 utilities which report making coating resistance measurements after the cables are in operation, 6 make these measurements annually, 2 semi-annually, one semi-annually to annually, one every 2 to 3 years, one takes measurements on cathodic protection system 3 times daily and one has made meas-

TABLE 7—H. Cathodic Protection

H. CATHODIC PROTECTION

1-a Type of cathodic protection used, if any?

1-b If not now used, do you plan to apply cathodic protection when coating resistance deteriorates?

1-c If so, have you established a value of resistance which would determine when to apply such protection and

what is this value?

2-a Where are rectifiers (if used) and anodes installed?

2-b How many anodes are used and how are they distributed and located with respect to the line?

3 What cathodic protection voltage (pipe-to-earth potential) is used?

Company	Question H-1-a	Question H-1-b	Question H-1-c	Question H-2-a	Question H-2-b	Question H-3
A	(See A-H-1-a below.)	Probably.	Have not established resistance value.	(See A-H-2-a below.)	(See A-H-2-b.)	0.3 to 2.0 volts pipe negative to soil or water.
B	None. Installation and maintenance of high resistance coating is depended upon.	Cathodic protection will be used as a last resort.	No.			
C	Magnesium anodes installed in each manhole.	Magnesium anodes considered advisable now to protect painted pipe and auxiliaries in manholes.		Rectifiers not used—and will not be used.	One magnesium anode in or at each manhole.	—0.3 to —0.4 volt basic.
D	Floating battery between pipe and substation ground at terminals.			At terminals only to maintain battery.	Station ground mats are anodes.	Approx. 2 volts.
E	Magnesium anodes between manholes.			Magnesium anodes are installed 10 ft. below the pipe spaced midway between manholes and man holes and terminals.	Magnesium anodes are installed midway between manholes and between manholes and terminals.	No data at present.
F	None.	(See F-H-1-b below.)	No.	None.	None.	None.
G	(See G-H-1-a below.)	No information available on this condition.		(See G-H-2-a below.)		2 volts.
H	Single cell battery.			(Not reported.)		Approx. 2 volts.
I	Forced drainage—battery connected between pipe (negative) and ground.		Protection is applied on standby basis at time of installation.	Rectifier and battery installed at terminations. Zinc anodes installed at 1/2-mile intervals (test station location).	Two zinc anodes at each test station 1/2-mile intervals approx. 30 ft. from line.	—2.1 volts to zinc anodes.
J	Rectifier, galvanic anodes, stray railway current drainage.			(See J-H-2-a below.)	(See J-H-2-b below.)	—0.85 volt to CuSO ₄ .
K	2-volt—d-c negative pipe-to-earth potential is applied.			A 2-volt cathodic-protection wet cell is located at one of the terminals.	(Not reported.)	2 volts.
L	None.	Yes.	No.			
M	Rectifier between pipe and carbon rods imbedded in crushed coke beds.			At seven locations in manholes.	98 anodes—located parallel with pipe about 20 ft. apart and approx. 10 ft. from pipe.	0.5 to 1.0 volt.
N	Magnesium anodes in manholes.		(See N-H-1-c below.)	Galvopak Mg anodes in 12 clay tile below floor level of manhole.	One in each manhole. Only 4 of 27 are connected at present.	0.3-volt shift negative. Min. —0.85 volt to CuSO ₄ half cell.
O	None.	Yes.	(Not reported.)			
P	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)
Q	Rectifier, dry disk (copper oxide).			At both terminals.	No anodes are installed.	3.0 volts normal. 4.0 volts with rectifier energized at active rectifier end.

A-H-1a. Usually 2-volt storage cell connected in pipe grounding cable. Also cathodic protection by motor-generator or selenium rectifier to drain pipes at river crossings.

G-H-1a. 2-volt battery capable of passing maximum fault current in parallel with 50-amp rectifier to protect lines I & II. Similar installation planned for III & IV. No cathodic protection on V & VI.

F-H-1b. A line currently under construction includes a river crossing. This line is buried in a trench under the river. Measurements are difficult and costly to make and it would be virtually impossible to repair any coating defects found. For these reasons this line will have cathodic protection from either batteries or a rectifier, if anodic exposures are found.

N-H-1c. Consider that any coated line should have sufficient protection to maintain 0.3-volt shift to earth.

A-H-2a. Rectifiers are installed at stations to keep storage cells charged. Also a rectifier is used at a river crossing to drain current to a sheet piling anode at shore line.

G-H-2a. Rectifier in parallel with battery installed at same terminal with pumping equipment. Present installation connected to street car system rails which serve as ground bed. No experience with anodes.

J-H-2a. A forced-drainage rectifier tied to adjacent trolley system rails is located 4 miles from one terminal of the 11-mile line and about one mile from a substation. Zn-anode beds are located at the line terminals and at a second substation. Also 38 individual Zn anodes are distributed roughly at 0.3-mile spacings.

A-H-2b. One set of pipes in underwater tunnel connected to motor-generator set which drains current to a section of C.I. pipe

urements once since installation in 1949 but believes annual measurements are desirable.

For the 12 utilities which report making coating resistance measurements after the cables are in operation, 8 utilities regularly schedule these measurements. Four utilities do not regularly schedule them but 2 of these expect to schedule them regularly in the future, and another makes these measurements when it is practicable to obtain an interruption.

Of 12 utilities reported making coating resistance

measurements after the cables are in operation, 8 utilities make these measurements only on terminal-to-terminal lengths. Four utilities obtain sectionalized data.

Rates of Resistance Depreciation

Rates of depreciation of average resistances of pipe coatings were as follows. Of 15 utilities reporting, one observed a ten-fold decrease in resistance in $2\frac{1}{2}$ years, one observed a decrease to $\frac{1}{10}$ to $\frac{1}{35}$ of

4-a What magnitudes of cathodic protection currents are involved?

4-b What proportions of these currents are picked up by the pipe-line?

5 For the cathodic protection currents used, what is the average current density per sq ft of pipe surface (ma/sq ft pipe area)?

6 What provision is made to minimize anodic exposures of other underground structures resulting from the cathodic protection applied to the pipe-line?

7 How is cathodic protection monitored (how frequently checked for potential and/or current)?

Question H-4-a	Question H-4-b	Question H-5	Question H-6	Question H-7
Approx. 0.1 amp. per 10 miles of pipe.	Approx. 0.1 amp. per 10 miles of pipe. (Approx. 100 percent.)	0.001 ma/sq. ft.	(See A-H-6 below.)	Usually a monthly check of current and state of battery charge.
(See C-H-4-a below.)	All. (Magnesium anodes in each man-hole.)	Less than .03 ma/sq. ft. (From magnesium anodes in each man-hole.)	None as yet. Limited protection currents and surveys are expected to minimize exposure of other sub-structures.	Once or twice a year.
1.5 to 2 amp.	Approx. 1.0 amp. (Cathodic protection currents involved are 1.5 to 2 amp.)		Maintain cathodic protection currents as small as possible. Maintain wide separation between protected and unprotected structures.	Battery checked weekly.
No data at present.	No data at present.	No data at present.	No data at present.	No data at present.
None.	None.	None.	None.	None.
Approx. 3 to 5 amp. per circuit for lines I & II.	(See G-H-4-b below.)	0.07 ma/sq. ft.	No provision at present. Expect problems when conversion of street cars to trackless trolleys is completed in area of lines I & II.	Remote alarms provide for failure of rectifier. Potential checked every 24 hr. Storage battery checked once each week.
$\frac{1}{4}$ amp.	(Not reported.)	(See H-H-5 below.)	In case a ground develops on pipe due to break in the coating or for any other reason, an alarm is sounded in office of System Load Dispatcher.	Normally by-passed ammeter. Read every two days.
1.07 amp. average.	36 percent.	0.02 ma/sq. ft.	None.	Monthly.
(See J-H-4-a below.)	Probably less than 5 percent.	This criterion is not used.	(See J-H-6 below.)	Quarterly.
Approx. 10 ma.	100 percent.	274×10^{-6} ma/sq ft.	The pipe-line has an isolated ground, and the coating resistance is maintained at a high value.	Cathodic protection currents are read by opening switch blades shunted across milliammeters. Potential is read from the charger voltmeter. These readings are taken three times daily.
4 to 12 amp.	No data.	No data.	None.	Semi-annually.
26 milliamp.	100 percent when capacitors are installed at terminations.	0.0002 ma/sq ft.	No problem with the low value of current involved.	Once a month.
(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)	(Not reported.)
Approx. 150 milliamp d.c. measured.	Approx. 100 percent.	0.003981 ma/sq ft.	Not necessary with current values used.	Monthly, and following reports of line surges.

submerged in the river. A second set of pipes crossing New York harbor connected to selenium rectifier which drains current to sheet piling anode at shore line.

J-H-2b. 37 individual anodes (Zn in artificial backfill) roughly 0.3 mi apart, located in trench bottom; also 3 beds of ten Zn anodes $96'' \times 3'' \times \frac{1}{2}''$ at substation and pipe terminals. Anodes along line are $48'' \times 3'' \times \frac{1}{2}''$. Trolley system rails are also used as an anode for a forced-drainage rectifier at an intermediate location.

C-H-4a. Less than 1 amp, most of which will enter the pipe system at manholes and the single-conductor pipes at the terminals.

J-H-4a. Rectifier, roughly 25 amp. Most anodes pick up rather than discharge current. Stray railway drainage presently about 50 amp.

G-H-4b. Very little since current measured at test points near field terminals is approximately equal to current at substation.

H-H-5. Very small—approx. $\frac{1}{2}$ amp for entire installation (approx. 0.007 ma/sq ft).

A-H-6. (a) Provision and maintenance of high resistance coating on pipe.

(b) Preliminary tests jointly with other utilities using temporary installation of cathodic protection prior to permanent installation.

J-H-6. Resistance bonds to common neutral which is tied directly to water mains and indirectly to bare cast-iron gas mains. Other crossing foreign lines are cathodically protected.

original value in 2 years and then to about $\frac{1}{125}$ of original value in 6 years, one observed a decrease to about $\frac{1}{13}$ of original value in approximately 4 years and one reports there has been no noticeable change in the voltage and current requirements of the cathodic protection system. The other 11 utilities report sufficient data not available to indicate rate of decrease of resistance.

E. Grounding Provisions

All 17 utilities reported whether their pipe lines are grounded at terminals and the grounding means used. Nine utilities ground their pipe lines solidly at the terminals, with one of these reporting some of its pipe lines grounded instead through 2-volt storage cells and another reporting grounding solidly at one terminal and through a 2-volt storage cell at the other. Three utilities ground their pipe terminals through 2-volt storage cells. Three utilities isolate the pipe terminals from ground by low-voltage gaps. One utility connects the pipe terminals to ground through 3000-mfd capacitors. One utility does not ground the pipe at the terminals.

Provision for Fault Currents

Of 8 utilities reporting that pipe is not directly grounded at terminals, provision for fault current return is made as follows. Four utilities provide connection to ground through low-voltage gaps and 2 ground the pipe through storage batteries of adequate capacity to carry fault current. One utility grounds through a cathodic protection cell but does not state whether it is adequate to carry fault current. One utility makes no provision for fault current return.

Of 15 utilities reporting, 11 do not ground the pipe in manholes. Two utilities ground the pipe in manholes to driven ground rods. One utility grounds in manholes to magnesium anodes and another plans to install magnesium anodes in its manholes.

Of 17 utilities reporting, 16 do not ground the pipe to other structures en route. One utility connects drainage bonds to other structures, where required.

F. Drainage Bonds

Of 16 utilities reporting whether or not they use drainage bonds connected to the pipe, 13 do not use such bonds and 3 do use them.

Of 16 utilities reporting, 3 use drainage bonds. For these 3 utilities using drainage bonds, the bonds are designed to drain 50 amp, 50 to 100 amp, and 180 amp, respectively.

G. Stray Current Measurements

The following provisions are made for measurement of stray current along the pipe. Of 16 utilities reporting, 9 bring out leads attached across a calibrated section of pipe for measurement of stray currents. One utility uses 2 copper lugs brazed to the pipe, 10 feet apart, in each manhole. One utility brings out ground leads terminating at a nearby manhole, at 3 different points along the pipe line. One utility takes voltage-drop measurements on a bond wire across joints in manholes. One utility contemplates using lengths between manholes, if necessary,

and calibrating as needed. Three utilities make no provision for measurement of stray current along the pipe.

Use of Pipe as Shunt

Of 12 utilities reporting use of the pipe as a shunt for measuring stray currents, 6 use pipe-shunt resistances of from 380 to 1000 microhms. Three of these 6 utilities also report corresponding pipe distances of 40, 50-80 and 116 feet, respectively. Three utilities report using shunts of 10, 80 and 100 feet of pipe, respectively, without specifying corresponding resistance value. One utility states the resistance used varies because random lengths of pipe are used. One utility expects to use length between manholes, if necessary, and calibrate as needed. One utility uses a 4/0 bond across the joint in the manhole, corresponding to a resistance of 50 microhms for a 1-foot length of the bond.

Of 12 utilities reporting use of the pipe as a shunt for measuring stray currents, measuring points are located along the pipe lines as follows. Seven utilities have calibrated-pipe shunts at each manhole, 2 space them at approximately $\frac{1}{2}$ -mile intervals and one at roughly 0.3-mile intervals. One utility expects to use lengths between manholes if measurements are necessary. One utility uses a bond wire around the joint in each manhole as a current-measuring shunt.

Pipe-to-Earth Potential Measurements

Thirteen utilities report they measure pipe-to-earth potentials and 2 utilities report they do not. Of the 13 utilities making these measurements, 7 use CuSO_4 electrodes (4 of these using high resistance voltmeters), 2 use buried zinc electrodes, one measures between pipe and clean steel probe with a 400,000-ohm voltmeter, one measures between pipe and a lead plate in wet manhole sump with a recording voltmeter, one measures from pipe to copper ground rod or to steel rail and one did not state the kind of electrode used. One of the utilities using CuSO_4 electrodes also uses the lead sheath of adjacent buried thermocouple as an electrode.

Of 16 utilities reporting, 11 make potential measurements from pipe to other structures. Five utilities do not make such measurements.

Stray Current Surveys

Of 15 utilities reporting, 12 make regularly scheduled stray current and potential surveys and 3 have no regular schedule, but one of these is planning a regular schedule in the future. Among the 12 utilities regularly scheduling these surveys, 5 make them annually, 4 semi-annually, one quarterly, one monthly, and one biennially.

H. Cathodic Protection

Of 16 utilities reporting the type of cathodic protection used, if any, 12 use cathodic protection and 4 do not. Among the 12 utilities applying cathodic protection, 6 use 2-volt storage cells, one of the latter also using a motor-generator or selenium rectifier to drain pipes at river crossings and another having this protection on 4 of its 6 pipe-cables with the other 2 unprotected. Three utilities use magnesium anodes installed in each manhole or per section. Three utili-

ties use rectifiers, one of these also using zinc galvanic anodes.

Of the 4 utilities which reported cathodic protection was not now used, 2 plan to install it when the coating resistance deteriorates, one expects to use it, if anodic exposures are observed, on a line which includes a river crossing inaccessible for measurement and repair and the fourth will use it as a last resort. One utility using cathodic protection on 4 of its 6 pipe-cables has no information on plans for using cathodic protection on the other 2 pipe-cables.

Of 3 utilities reporting they do not use cathodic protection but would consider applying it if coating resistance deteriorates sufficiently, none has established a value of resistance which would determine when to apply such protection.

Use of Rectifiers

Of 15 utilities reporting whether rectifiers are used and where rectifiers and anodes are installed, 8 use rectifiers. Among these 8 utilities, 5 use the rectifiers to maintain charge on cathodic-protection storage batteries at line terminations (anodes are station or substation ground systems), with one of these 5 utilities also using a rectifier at a river crossing to drain current to a sheet piling anode at shore line. One utility has rectifiers at both terminals with no anodes installed. One utility has rectifiers with adjacent carbon anodes, installed at 7 locations in manholes. One utility uses a rectifier for forced drainage, at a location intermediate of the ends of the line, tied to adjacent trolley rails.

Eleven utilities reported on the number of anodes used and their distribution and location with respect to the pipe line. Seven of these 11 utilities use anodes other than the conventional station or substation ground. Three of these 7 utilities use magnesium anodes, 2 locating them in or at each manhole, and the other installing them midway between manholes and terminals. Two utilities use zinc anodes, one using 2 anodes 30 feet from line at each half-mile test station and the other using individual anodes in trench bottom spaced roughly 0.3-mile apart. The latter utility also has 3 beds of 10 zinc anodes at line terminals and an intermediate substation and also uses trolley rails as a forced-drainage anode. One utility has 98 carbon anodes adjacent to 7 manholes, the anodes being located parallel to pipe about 20 feet apart and approximately 10 feet from pipe. One utility applies cathodic protection to river crossings and uses a submerged CI pipe as anode in one case and shore-line sheet piling as anode in another case.

Protection Voltages Maintained

The cathodic protection voltages (pipe-to-earth potentials) for the 12 utilities using cathodic protection, are: Five of these utilities use a pipe-to-earth potential of -2 volts or approximately -2 volts. Two utilities use a potential of -0.85 volt to CuSO_4 , one of these also using a 0.3-volt negative shift. One

utility uses a potential of -0.5 to -1.0 volt. One utility uses -0.3 to -0.4 volt and another -0.3 to -2.0 volts. One utility uses -3.0 volts. One utility reports no data available.

Magnitudes of Currents

Magnitudes of cathodic protection currents for the 12 utilities reporting use of cathodic protection were as follows. Three utilities report cathodic protection currents in the range 3 to 25 amperes, 4 report currents in the range 0.5 to 2 amperes, and 4 report currents in the range 10 to 150 milliamperes (one of these reporting 0.1 ampere per 10 miles of pipe). One utility reports no data available.

Of the 12 utilities using cathodic protection, 9 reported the following proportions of cathodic protection currents which are picked up by the pipe lines. Five utilities report 100 percent or approximately 100 percent of this current is picked up by the pipe line. One utility reports about 50 percent of this current is picked up, one reports 36 percent, another reports 5 percent, and one reports very little is picked up.

Of the 12 utilities reporting use of cathodic protection on their pipe lines, 8 supplied data on average cathodic protection current per unit area. The range of average protection current for these 8 utilities was from 0.0002 to 0.07 ma/sq ft pipe area.

Minimizing Anodic Exposures

The 12 utilities which use cathodic protection report as follows on provisions made for minimizing anodic exposures of other underground structures. Five of these utilities make no such provisions and 2 report this is not a problem with the low values of current used. Three utilities maintain coating resistance at a high value, one of these also having an isolated ground, another maintaining wide separation from unprotected structures and the third making preliminary tests jointly with other utilities having adjacent underground structures. One utility uses resistance bonds to other structures. One utility has provision for an alarm in case a ground develops on pipe due to break in the coating.

For the 12 utilities using cathodic protection, monitoring of this protection (frequency of check for potential and/or current) was reported as follows. Five utilities use storage batteries on which check readings are taken at intervals ranging from as often as 3 times daily up to one a month. Of the 3 utilities using magnesium galvanic anodes, one utility reports taking readings monthly, another reports checking once or twice a year, and the third reports no data at present. Two utilities using rectifiers and zinc anodes report taking check readings monthly and quarterly, respectively. One utility using distributed rectifiers and carbon anodes checks them semi-annually. One utility having a rectifier at each end of its line and no special anodes, takes readings monthly and following reports of line surges.



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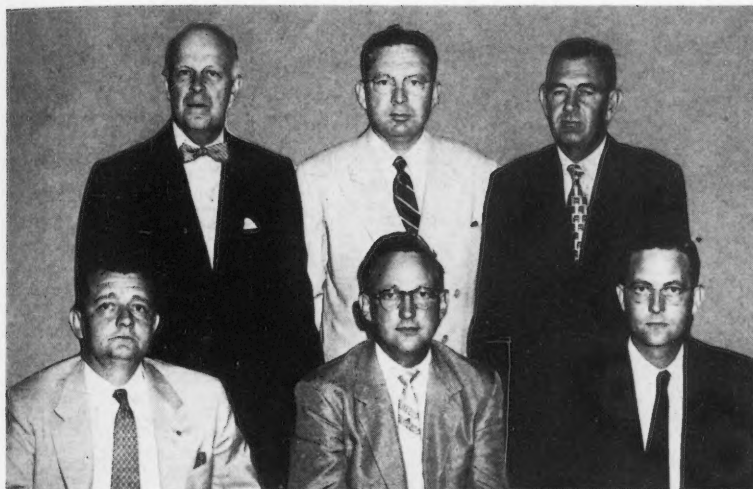
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NACE News



MEMBERS OF WATER FLOODING PANEL at Odessa, Texas, Monday, August 11 are, left to right: Back row, Dr. C. C. Knobloch, Consultant Bacteriologist, Tulsa; J. H. Sullivan, Atlantic Refining Co., Dallas; George Buckles, Buckles and Hostetler, Monahans; front row, H. L. Bilhartz, Production Pftis, Inc., Dallas; Bob Warden, Shell Oil Co., Odessa, and J. L. Crittenden, Humble Oil and Refining Co., Midland. (Odessa American Photo.)

Tentative Program For Los Angeles Meeting Is Adopted

A tentative technical program has been adopted for the November 18-19 Meeting of Western Region NACE at Los Angeles. The program will be as follows:

November 18

9:30 to 10 am—Opening and keynote speakers.

10 am on—Marine Corrosion Session. L. L. Whiteneck, Board of Harbor Commissioners, Long Beach, Cal., chairman.

November 19

9 am—Waste Disposal Session. C. G. Munger, Amercoat Corp., South Gate, Cal., chairman.

2 pm—Pipeline Corrosion Round Table. N. K. Senatoroff, Southern Counties Gas Co. of Cal., Los Angeles, Cal.

At a meeting of Western Region Division officers July 29, when these decisions regarding the November meeting were made it also was indicated that the 1955 Western Region Division Meeting probably would be held at San Francisco.

Tour of Procter & Gamble Plant Scheduled Sept. 28

A plant tour and inspection of the Procter & Gamble Company at Ivorydale, Ohio is scheduled by Southwestern Section NACE on September 28. The tour will begin at 2:30 pm and last until 6 pm when members will gather at Shuller's restaurant.

Following dinner at 6:30 pm a business meeting will be held and a discussion of corrosion problems led by George Lockman, Head of the Metallurgical Section, Engineering Division, Procter & Gamble.

SHORT COURSE CALENDAR

1954

Nov. 15-17, UCLA, Los Angeles, California; Protective Coatings

November, University of British Columbia, Vancouver, British Columbia, Canada

1955

Jan. or Feb., UCLA, Los Angeles, Cal.
Feb. 2-4—University of Toronto, Hart House Theater, Toronto.

Feb. 16-18—Tulsa Section, Sixth Annual Short Course. Mayo Hotel, Tulsa, Okla.

Fall—Washington University, St. Louis, Missouri.

Large Group Attends Water Flooding Talks At Odessa Sponsored by 4 Technical Groups

More than 400 persons attended a joint meeting of four technical groups at the Lincoln Hotel, Odessa to participate in a panel discussion on water flooding. The meeting was attended by members of Permian Basin Section NACE and members of AIME, TSPE and ASCE, August 9.

A panel discussion was conducted by H. L. Bilhartz, Production Profits, Inc., Dallas, moderator; E. H. Buckles, Buckles and Hostetler, Monahans; Leon Crittenden, Humble Oil Company, Midland; C. C. Knobloch, consultant, Tulsa and J. H. Sullivan, Atlantic Refining Co., Dallas. The panel discussed design of a water flooding program from preliminary evaluation of the property to completion and operation problems encountered.

The discussion of bacteria normally encountered in water injection systems, and the methods used to combat them was of special interest to corrosion engineers. Sulfate reducing anaerobic bacteria were extensively discussed by Dr. Knobloch.

Much discussion was aroused by the assertion of one panel member that in some instances normally incompatible waters might be used in water flooding without ill effects. An illustration given was of the use of waters containing barium and sulfates which ordinarily could be expected to precipitate barium sulfate which might plug formations and cause loss of production.

Gehant Will Speak

John Gehant of the Devoe & Raynolds Company will speak to the Metropolitan New York Section at its September 22 meeting on The Use of Epoxy Coatings in Industrial Maintenance. Mr. Gehant, an authority on the development and use of epoxy resins, will show illustrations and cover a broad field.

Edmonton Section Elects Officers at July Meeting

At the July 2 meeting of Edmonton Section held at the Seven Seas Restaurant, the following officers were elected: Frank W. Hewes, Canadian Protective Coating Ltd., chairman; G. L. Spackman, Imperial Pipe Line Co., Ltd., vice-chairman; E. Hochhausen, Redwater Water Disposal Co., Ltd., secretary; R. B. Skinner, Canadian Equipment Sales & Service Co., treasurer.

Mr. Spackman is to serve as chairman of a committee which will prepare rules and regulations for the Edmonton Section for submission to the Canadian Region Board. The membership advocated a corrosion museum and library for the local section and proposed that the section hold monthly meetings with every third or fourth meeting to be held jointly with other engineering and technical societies in the Edmonton area.

Dallas Pipe Line Round Table Panel Is Named

The 1955 NACE Eleventh Annual Conference and Exhibition will be held at Chicago, March 7-11.

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Permian Basin Section Meetings Are Scheduled

Meetings scheduled by Permian Basin Section are as follows:

September 13—Speakers, Lyle Shepard, Shell Pipe Line Corp. and A. B. Campbell, NACE, Houston.

October 4—B. G. Iverson, Kewanee Oil Co. will speak on Corrosion in McElry Field.

November 8—Panel discussion on refinery corrosion.

December 13—Jack Williams, National Tank Co., Odessa, will discuss tank corrosion.

January 10—Panel discussion on casing corrosion.

San Francisco Bay Area Section Program Outlined

Three meetings have been scheduled by San Francisco Bay Area Section as follows:

September 22—E. O. Kartinen of Signal Oil and Gas Co. will talk on Effects of Corrosion and Erosion on Some Steel Piers Along the Southern California Coast.

October 20—L. P. Sudrabin, Electro Rust-Proofing Corp. will talk on Criteria Used in Cathodic Protection.

November 17—D. C. Erdman, Electro Circuits, Inc. will talk on Ultrasonic Testing.

All meetings will be in San Francisco.

Discussions of technical material printed in Corrosion are not limited to those actually originating at the presentation of papers at meetings.

Members of the panel that will conduct the Pipe Line Round Table to be held on the afternoon of Friday, October 15 during the Dallas South Central Region NACE Conference have been named as follows by J. N. Hunter, Jr., chairman of the round table:

T. L. Canfield, Consolidated Gas Utilities Corp., Lawton, Okla.; G. L. Doremus, Cathodic Protection Service, Houston; M. B. Grove, Interstate Oil Pipe Line Co., Shreveport and Y. W. Titterton, Pipe Line Anode Corp., Tulsa.

The meeting to be held October 14-15 will have six symposia of technical papers and two discussion sessions. Symposia are scheduled on cathodic protection, protective coatings, inhibitors, processing plant corrosion problems, pipe line corrosion and oil and gas production. Discussions will consist of a question and answer audience participation session and panel on oil and gas pipe line transportation.

Several technical committee meetings, especially of those concerned with the petroleum industry, are expected to be held.

Pokorny Accepts Post On Policy Committee

Jerome J. Pokorny, Cleveland Electric Illuminating Co., Cleveland has accepted appointment on the Policy and Planning Committee of the National Association of Corrosion Engineers. A member of NACE since 1949, Mr. Pokorny has served on technical committees and currently is vice-chairman of T-4B-2 on Cathodic Protection, a group in the utilities committee.

H. A. Swem

H. A. Swem, vice-president and general manager of Texas Gulf Sulphur Co., 63, died at Newgulf Hospital August 8 after suffering a heart attack. Mr. Swem was corporate member for his company in NACE.

A graduate of Stanford University, he began working for the company's engineering department 35 years ago. He was named assistant general manager in 1942 and vice-president in 1953.

Library Rate Reduced

The CORROSION subscription rate for libraries of educational institutions and public libraries in Canada has been reduced to \$4 for 12 issues. This makes the Canadian rate for this classification of subscriber the same as the rate in the United States.

Munger Will Address N. E. Region Meeting

C. C. Munger, director of research for Amercoat Corp., South Gate, Cal., will be principal speaker at a Northeast Region NACE meeting October 19 at Baltimore. Baltimore Section has charge of arrangements.

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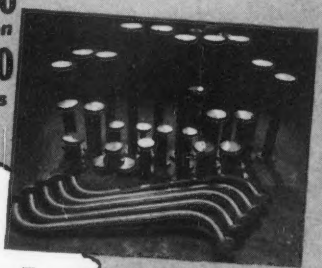
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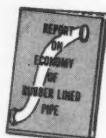
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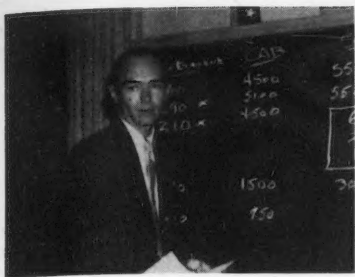


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W. M. Thornton

Houston Hears Thornton On Plastic Pipe Tests

W. M. Thornton, Atlantic Refining Company, Dallas, spoke on oil field structural plastics at the August 10 meeting of the Houston Section. Mr. Thornton, co-chairman of Committee T-1J, presented data collected by the committee and by himself. The need of more data pertinent to the oil industry was cited. Much of the physical strength characteristics presented by plastic pipe manufacturers and raw material suppliers are arrived at by short term tests, with no means of predicting long term life, he said. As an illustration, Mr. Thornton cited a typical section of pipe whose burst in air on short term test varied between 700-1000 psi at temperatures of 40 to 140 degrees F, but on long term tests, in water, the burst was 105 psi at 110 degrees F.

Mr. Thornton reported on data obtained by T-1J covering 73 plastic pipe installations, 24 of which had one or more failures. Many of the failures could be traced to excessive internal pressure over and above recommendations. This data also confirmed the fact that plastic pipe should be buried, but that snaking a line in a trench is generally not sufficient to take care of expansion and contraction. Rather, the line should be equipped with Dresser or similar type couplings.

A lively question and answer period followed Mr. Thornton's presentation.

Programs scheduled so far by Houston Section are:

September 14—Kelley's Restaurant, J. D. Sudbury, Continental Oil Co., Ponca City, Okla. on Tanker Corrosion.

October 5—Kelley's Restaurant, C. L. Woody, United Gas Pipe Line Co., Houston, on Application of Some of the Instruments Used for Cathodic Protection Work.

An arrangements committee has been named for the section as follows: Joy T. Peyton, F. W. Gartner, Jr., Jack G. Davis and Quentin R. Estep.

Chinese Science Bulletin

A copy of Volume 1, No. 5 of the Bulletin of the Chinese Association for the Advancement of Science dated December, 1953 has been received by Central Office NACE. The periodical is published by the Chinese Association for the Advancement of Science at 59, Kuan Chien St., Taipei, Taiwan, China.

The December, 1953 issue, among other things includes articles on archeology, ecology, mining, mathematics and agronomy.

Houston Section to Drive For Corporate Members

A corporate membership drive, developing an attractive section meeting program and putting a speaker's bureau into operation are three of the principal objectives of new Houston Section officers, according to Joseph Caldwell, Humble Oil and Refining Co., section chairman.

Heading the corporate member drive is Sidney Smith, Napco Paint and Varnish Works. Mr. Smith is himself a corporate member for his firm. Last year the Houston Section obtained 25 members, a large proportion of the total obtained by the national organization. Plans are being made to conduct another determined drive.

Believed to be the first such program inaugurated by a local section, Houston has put its speakers' bureau into operation. Bill Wood, Products-Research-Service heads the bureau, the purpose of which is to provide speakers of proved technical ability to address student members of technical societies who are interested in studying corrosion.

John T. Richards Honored

John T. Richards, Penn Precision Products, Inc., Reading, Pa. has been given the Sam Tour Award for his paper "The Corrosion of Beryllium Copper Strip in Sea Water and Marine Atmospheres" which was presented at the 1953 annual meeting of American Society for Testing Materials.

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Miscellaneous

Resistance of Aluminum Alloys to Weathering by C. J. Walton, D. O. Sprowls and J. A. Nock, Jr., and Resistance of Aluminum Alloys to Contaminated Atmospheres by W. W. Binger, R. H. Wagner and R. H. Brown......50

Final Report—Effect of Exposure to Soils on the Properties of Asbestos-Cement Pipe by Melvin Romanoff and Irving A. Denison......50

Laboratory Studies on the Pitting of Aluminum in Aggressive Waters by T. W. Wright and Hugh P. Godard......50

Causes of Corrosion in Airplanes and Methods of Prevention by N. H. Simpson......50

Salt Spray Testing Bibliography by Lorraine Voight......50

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1951—January, February, March, October.

1952—March, April.

1954—January.

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5-Year Index, 1945-49 inclusive and

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Index to Vol. 7..... December, 1951

Index to Vol. 8..... December, 1952

Index to Vol. 9..... December, 1953

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HOUSTON

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TEXAS



Technical Committee News

Report on Vinyl Coatings Readied for Publication

Kahn Resigns After Completion of Report On Pipe-Type Cables

Frank Kahn, Philadelphia Electric Company, has resigned as chairman of Task Group T-4B-4 on Corrosion and Protection of Pipe-Type Cables after completing the committee's first interim report. The report, titled Pipe-Type Cable Corrosion Protection Practices in the Utilities Industry is published in the September, 1954 issue of *Corrosion*. Reprint copies are available. The report is published in the plies received by the committee to a questionnaire investigating current practice in the protection of pipe-type cables.



Kahn

Herbert W. Dieck, Long Island Lighting Co., Mineola, N. Y. has succeeded Mr. Kahn as chairman of the task group.

Mr. Kahn is senior technical assistant in the testing division of the Philadelphia Electric Company. During 25 of his 31 years with the company he has been concerned with corrosion control, especially in problems associated with lead sheathed cable. A graduate of the University of Pennsylvania with a B.S. in electrical engineering and from Temple University with an LL.B. degree, he is a charter member and past officer of Philadelphia Section NACE. He also is an active member of AIEE and the Philadelphia Bar Association.

T-3F Members to Give High Purity Water Session at Chicago

A symposium on Corrosion by High Purity Water is being prepared for presentation during the Eleventh Annual Conference and Exhibition of the National Association of Corrosion Engineers in Chicago next March. D. J. DePaul, Atomic Power Division of Westinghouse Electric Corp., Pittsburgh, chairman of Unit Committee T-3F on Corrosion by High Purity Water, is chairman of the group, one of the newest organized by the association.

The premise under which the group as organized was that it would be useful to cover in a general way all corrosion problems resulting from exposure

(Continued on Page 6)

Steiner Represents NACE On Coating Test Group

Robert H. Steiner, Director of Research, Atlas Mineral Products Co., Mertztown, Pa. and chairman of Unit Committee T-6R on Coatings Research has been appointed to represent the National Association of Corrosion Engineers on a protective coatings project sponsored by the Federation of Paint and Varnish Production Clubs. He will act in an advisory capacity to furnish technical data.

The committee charged with responsibility for the project met May 6 and reached the following conclusions: 1) 8-mil coatings are not generally used in industry and probably will not be used in the test program. 2) Thicknesses less than 2 mils may be tested. 3) Sites of exposure of test specimens, as yet unselected, will be in marine, moderate industrial and semi-rural environments. 4) 10-gauge hot rolled steel panels measuring 6 by 12 inches and all from one lot if possible, will be used. 5) Angle iron specimens will be from one lot if possible. 6) Close analysis materials will be preferred. 7) One type of specimen will be flat and the other will have a piece of angle iron welded near the center.

Panels will be 50 to 80 percent rusted prior to painting to eliminate mill scale and more closely approximate field practice.

No decision concerning the university that will conduct the tests has been reached.

Twelfth Report Is Made On Sulfide Stress Probe

The twelfth report by Unit Committee T-1G on Sulfide Stress Corrosion Cracking has been made by R. S. Treseeder, Shell Development Co., California, chairman. The report to Group Committee T-1 covers activities of the group for the period December, 1953-June, 1954 and its principal content concerns the sulfide stress corrosion research project now underway at Yale University under direction of Professor W. D. Robertson.

In the discussion on what has been accomplished to date it was reported in general that investigations on the susceptibility to cracking of nickel steel have been made. These were conducted under the assumptions the susceptibility was dependent on: a) purity of the base alloy with respect to carbon, nitrogen and other impurities; b) structure, martensite, ferrite and austenite; c) austenitizing temperature and tempering tem-

(Continued on Page 7)

Resistance to Water, Corrosives; Limitations Outlined in Detail

A report on vinyl coatings prepared by Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion has been approved and is scheduled tentatively for publication in *Corrosion's* October, 1954 issue.

The committee defines vinyls as those polymers of vinyl chloride and copolymers of vinyl chloride with vinyl acetate, vinylidene chloride and other monomers in which vinyl chloride is the major component of the copolymer usually referred to as polyvinyl chloroacetates. In describing vinyl coatings the committee reports that vinyl compounds evaporated from solvent solutions are used extensively as maintenance coatings in corrosive environments. Properties of the material are such that it resists most inorganic salts, alkalis and acids and while not recommended for strongly oxidizing conditions, it does have better resistance to oxidizing environments than most other organic corrosion barriers. Electrical characteristics are excellent making it applicable for use as wire insulation, electroplating rack coatings and for isolating piping and equipment from stray or galvanic currents.

Forms in which vinyls are available and most generally used for corrosion mitigation include the following:

1. Coatings evaporated from solvent solutions.
2. Extruded shapes.
3. Molded sheets.
4. Dipped, sprayed or troweled coatings or linings.

For continuous exposure to highly corrosive media thick applications of vinyl sheet or plastisols are preferred.

Besides variations in pigment additions vinyl resins require plasticizers and heat stabilizers which remain in and become a part of the corrosion barrier. Deviations in performance and resistance will result when amounts and types of plasticizers are varied.

Because formulations vary among manufacturers the committee recommends service tests prior to extensive application of the coatings.

The report describes in detail resistance of vinyl coatings to water and moisture, inorganic acids, oxidizing conditions, organic acids, alkalis, salt solutions, solvents and oils. Limitations of properties of applied coatings and linings are included.

In describing application methods the report includes specific gravities, covering and weight per area for various coating thicknesses.

Although vinyl sheet and plastisol applications present no health or fire hazard from the vinyl itself, these factors

(Continued on Page 6)

POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Firms seeking employees, regardless of NACE membership, may run an advertisement of the same specifications indefinitely.
- Advertisements to other specifications will be charged for at standard rates.

Positions Available

Corrosion Engineers. Positions available for graduate electrical engineers or equal. Previous field and design experience in corrosion mitigation systems required. Extensive travel involved. Salary open. The Hinchman Corp., Engineers, Francis Palms Bldg., Detroit 1, Mich.

Sales Representatives for DEL Protective Coatings. Protected territories available to qualified individuals or companies. No objection to carrying non-competitive lines. Write David E. Long Corp., 220 East 42nd St., New York 17, N. Y.

Corrosion Engineer—Graduate engineer with field and design experience in cathodic protection systems. Extensive travel. Salary open. Harco Corp., P. O. Box 7026, Cleveland 28, Ohio.

Metallurgist—Wanted, recent graduate in metallurgy or metallurgical engineering with limited experience to operate metallurgical laboratory engaged in study of mechanical and corrosion failures of chemical process equipment. Located on Texas Gulf Coast. CORROSION, Box 54-19.

Sales Engineers—Good territories available for qualified men to sell well-known line of protective coatings. Salary and commission, plus expenses. Prufcoat Laboratories, Inc., 50 East 42nd St., New York 17, N. Y.

Metallurgist—Corrosion and/or electroplating experience required to supervise metallurgists and chemists in research and development of aircraft materials. Salary \$5940 or \$7040 per annum. Write Naval Air Material Center, Naval Base, Philadelphia 12, Pa.

Chemical Or Metallurgical Engineer

Leading chemical company has key position open in large eastern plant. Should have at least four years' experience with chemical plant corrosion problems. Responsibilities will involve corrosion investigation for new existing processes and development work in applying new materials of construction and corrosion prevention methods. Well equipped metallurgical corrosion laboratory and trained technicians available.

CORROSION, Box 54-21.

Positions Wanted

Electrical Engineer, BSEE, 38, married, veteran. Experience estimating, design and supervision of installations of power control, telemetering, carrier, radio, instruments, cathodic protection, etc. on industrial and gas pipe line. Summary on request. CORROSION, Box 54-10.

Metallurgist—MS, age 31, married. Extensive work in liquid metal, fused salt and aqueous corrosion. Report writing and supervisory experience. Want responsible research or development position in corrosion or physical metallurgy. Write CORROSION, Box 54-12.

Metallurgical Mining Engineer—Law degree also, seeks suitable executive, administrative position. Registered professional engineer, experienced corrosion, metallurgy, mining, production, research, government specifications, technical report interpretation. Presently self-employed. Available immediately. Write CORROSION Box 54-13.

Plant Engineer—Experienced development, project engineering (electrical, chemical, mechanical, ceramic), maintenance, cost reduction, application of corrosion engineering including metals, paints, lubricants, plastics and ceramics. Desire responsible position in East. Age 42, married. CORROSION Box 54-14.

Physical Chemist—PhD with BS in chemical engineering, age 34. Eight years experience in petroleum and chemical industries. Process engineering and investigations. Five years corrosion research in field and laboratory. Publications and patents. Experience in petroleum production, refining, transportation. Desire position group leader corrosion research and technical service. CORROSION—Box 54-20.

NACE's Western Region plans to hold two short courses each year. Attendance is not restricted to members of NACE.

Ordinarily preprint copies of papers presented at NACE meetings are not prepared by the association.

T-3F Members to Give—

(Continued From Page 5)

to high purity water at temperatures up to 650 degrees F. One of the committee's first objectives is to establish the suitability of materials for use in high purity water at elevated temperatures, with the expectation that problems to be considered later would include galvanic, stress and, intergranular corrosion, the effect of inhibitors, the resistance of metal plating and the value of other mitigative measures.

The volume of material collected so far will necessitate the committee devoting its time for a few years to analyzing and reporting existing information.

Problems related to special engineering considerations that may be studied include: clearances necessary to prevent seizure of infrequently moving parts; what frequency of movement between bearing surfaces is necessary for a given clearance to prevent seizure and the effect of nuclear irradiation on corrosion.

One member of the committee, summing up the need for it, says the development of nuclear power has brought about a number of corrosion problems for which current techniques in boiler design and operation are inadequate. Because technical developments in this area during the next few years are likely to be quite rapid, it is assumed activities of the committee will help in the quick accumulation of essential information.

Report on Vinyl—

(Continued From Page 5)

may be important considerations in connection with the adhesive solution primer because vinyl solutions are usually dissolved in ketone and aromatic hydrocarbons, the vapors of which are intoxicating. Flash point of the usual solvent is about 75 degrees F, and depending on formulation, may be as low as 20 degrees F. Special formulations may be made with flash points above 81 degrees F. These characteristics necessitate precautions against fire.

Included in the report also is a vinyl reference chart, which gives physical and chemical properties of the materials and indicates whether they are recommended, not recommended or recommended with limitations for use with various corrosive media.

WANTED—CORROSION ENGINEER Age 30-35

By Major Oil Company for Career Opportunity
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Must have degree in chemical, mechanical or electrical engineering. Must have previous cathodic experience with some years general corrosion experience. Must have at least three years industrial experience in corrosion engineering. Salary open. Will also consider applications from candidates with less experience for positions as assistant corrosion engineers.

Write or Apply in Person to

725 SHELL BUILDING, HOUSTON, TEXAS

May Accept Post as T-3G Group Chairman

T. P. May, The International Nickel Co., Inc., New York has accepted chair-



May

manship of Technical Group Committee T-3G on Cathodic Protection. The group is under T-3 General and was formed shortly after reorganization of the technical committees in March when it became apparent there were ramifications of cathodic protection outside the interest of group committees on the subject in T-2

Pipelines and T-4 Utilities.

The new group will direct its attention to studies not being considered by the other groups occupied with cathodic protection.

NACE members interested in joining the group are invited to communicate with Dr. May at his office, 67 Wall Street, New York, N. Y.

Procedure for Screening Inhibitors Is Revised

Unit Committee T-1K, at a meeting held in Dallas August 2 revised the Tentative Proposed Standardized Laboratory Procedure for Screening Corrosion Inhibitors for Use in Oil and Gas Wells. First draft of the tentative proposed procedure was distributed to members of the committee earlier in the year. This procedure was used by several laboratories in screening unknown inhibitors provided by the chairman of the committee. From the results of the laboratory tests, the committee was able to revise the procedure into what is now felt will be the final draft.

A significant change was made in the title of the procedure. As was reported previously in this section of Corrosion Magazine, the committee originally called the procedure Tentative Proposed Standardized Laboratory Evaluation Procedure for Screening Corrosion Inhibitors for Use in Oil and Gas Wells. The committee wishes it to be known it is not working on a method for evaluating inhibitors, but on laboratory procedure for screening only. For this reason the word "evaluation" was deleted from the title. The committee will present a paper on the laboratory procedure at the South Central Regional meeting to be held in Dallas on October 12-15, 1954. The entire report will be submitted to Group Committee T-1 at a later date and it is hoped the committee will submit the procedure for publication in Corrosion.

Reactor Station Toured

The National Reactor Testing Station, where the most intense flux of neutron radiation of any known reactor is developed, was opened for a guided tour of members of the press August 20. It is located at the Atomic Energy Commission's plant at Idaho Falls, Idaho.

Twelfth Report Is—

(Continued From Page 5)

peratures; d) retained austenite, and e) cold work.

Extensive comparisons have been made of the embrittlement resulting from cathodic charging of low carbon iron and from exposure to sulfide to determine the degree of equivalence between the effects. Considerable differences in susceptibility to cracking have been found but interpretation is dependent on the following variables: a) differential mechanical properties in the various structures; b) hydrogen absorption by the structures; c) effect of hydrogen on the fracture properties, e.g., ferrite can absorb larger quantities of hydrogen without failure than martensite.

Current work is to determine the quantity and rate of hydrogen absorption. Preliminary results indicate absorption depends on corrosion rate; therefore hydrogen saturation limit varies with

composition and is independent of structure for the same hydrogen sulfide environment. For constant charging conditions saturation appears to depend in a complex manner on both structure and composition. Conclusions regarding the cracking mechanism and possible preventive measures are dependent on the hydrogen analysis now in progress and correlation of the findings with previous data on cracking.

Future work is to include a study of possible correlation of susceptibility to cracking of alloys with their hydrogen content following exposure to aqueous hydrogen sulfide or following cathodic charging. Variables to be studied include composition, cold work, stress and heat treatment.

The influence of acidizing on cracking was discussed at a recent committee meeting. While no positive evidence was offered regarding its effect, opinions were expressed that acidizing probably would increase the tendency to crack.

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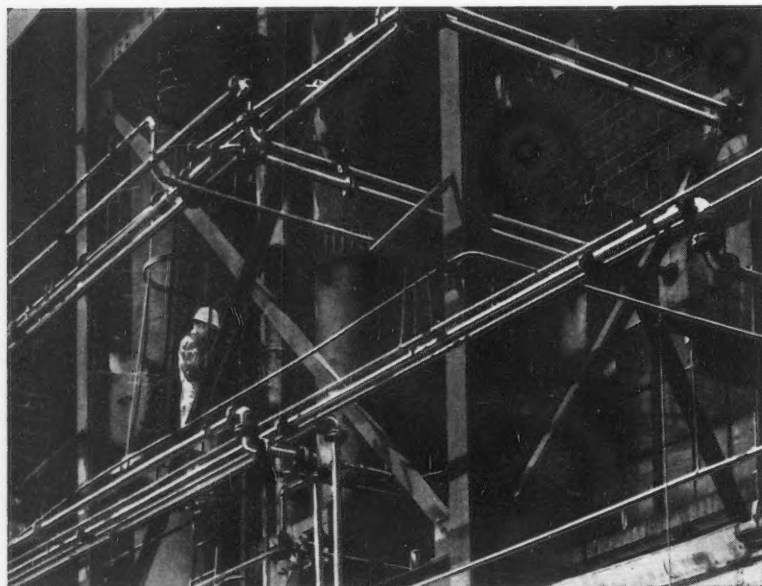
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Honnaker and Gabriel Are New T-6K Officers



Honnaker



Gabriel

New officers of T-6K on Corrosion Resistant Construction with Masonry and Allied Materials have been elected as follows: L. R. Honnaker, E. I. du Pont de Nemours & Co., Ltd., Wilmington, Del., chairman; G. P. Gabriel, Atlas Mineral Products Co., Mertztown, Pa., vice chairman. R. R. Pierce, Pennsylvania Salt Manufacturing Co., Philadelphia is retiring chairman.

The committee currently is securing data for a report designed to define the necessary requisites for corrosion-resistant construction with masonry and allied materials. The data will help the consumer who uses this type of construction and will be helpful to contractors in planning construction. Assignments within the committee call for groups to assemble data on cements, brick, interliners, brick sizes and surfaces, supporting structures and precast structures.

Provisions for Liaison Among Committees Made

The managing committee of the Technical Practices Committee, recognizing that communication between Technical Unit Committees working on similar subject matter is important, has approved addition of a paragraph to the Technical Committee Operation Manual to provide for liaison between unit committees. The addition to the operation manual is as follows:

Liaison. Any Unit Committee may establish liaison with another Unit Committee for the purpose of coordinating activities and exchanging information. The chairman of a committee desiring liaison with another committee may approach the chairman of that committee requesting that liaison be established. The methods and degree of liaison to be maintained by the committees concerned may be established and agreed upon by the respective committee chairmen. The liaison representative shall not have the power to vote in the committee with which liaison is established, unless he is otherwise a member of that committee. The committee chairman should normally serve as liaison for his committee, although he may appoint a member to so serve. The chairman of any committee may make changes in liaison personnel within his committee as the needs dictate.

The managing committee has no in-

(Continued on Page 9)

Service Reports Given on Oil Field Plastic Pipe

Data Are Compiled On 73 Installations In Oil Field Service

Field service reports on 110,000 feet of plastic pipe in oil field service have been compiled by Technical Committee T-1J on Oil Field Structural Plastics. The data were taken from replies to a questionnaire circulated among operators of 73 installations embodying pipe from 2 to 4 inches in size and including polyvinyl chloride, styrene-acrylonitrile copolymer and cellulose acetate butyrate materials.

Failure of 127 pieces or a little more than one percent of the pieces used was reported.

Compiled results of the questionnaire are summarized below:

Number of installations covered.	73
Pipe footage involved	
in installations	110,000
Number of installations experiencing failure	24
Number of installations retired..	4
Total number of plastic pipe joints and fittings	11,000
Number of pieces experiencing failure	127
Piece failures due to excessive temperature or pressure	18
Piece failures due to misapplication	2
Piece failures due to misfits, unsatisfactory cemented connections, substandard fabrication—all operating with recommended pressure level	107

The committee feels the following conclusions from the survey data might be adopted to reduce plastic pipe field failure:

Manufacturer

1. Adopt quality control and pressure tests to eliminate weak pieces.
2. Develop stress-strain-time curves at different temperature levels in water to determine the long-term strength of the plastic materials.

User

1. Use long-term strength data for installation design together with an appropriate safety factor.
2. Install suitable control facilities to avoid excessive temperatures and pressures.

Service Experience of Seventy-three Oil Field Installations of Butyrate and Styrene Copolymer Plastic Pipe.

On September 15, 1953 T-1J distributed questionnaires to 61 NACE members of T-1 and T-1J in an effort to determine the oil field experience of plastic tanks and pipe. The returned questionnaires describe the service experience of

the following installations: tanks, 12; extruded plastic pipe, 73; extruded plastic tubing, 5; reinforced plastic tubing, 9 and reinforced plastic pipe, 35. Because of the importance of reinforced plastic tanks and tubing, additional data are being sought so that a more comprehensive report can be prepared.

This article is a summary of data compiled from the questionnaire covering the oil field service experience of 73 extruded plastic pipe installations. Of the 73 installations covered herein, one used polyvinyl chloride pipe, 20 used a styrene-acrylonitrile copolymer pipe and 52 used pipe made of cellulose acetate butyrate.

Summary

These 73 installations consisted of over 110,000 feet of plastic pipe. Twenty-four of the 73 installations experienced one or more failures, the largest number occurring during the first few days of operation. Nineteen of the 24 installations which experienced failure were repaired and returned to service without further difficulties.

The 73 installations contained about 11,000 pieces, consisting of joints, couplings and miscellaneous fittings. The failures involved only 127 pieces, or between 1 and 1.3 percent of the total

(Continued on Page 10)

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- ★ Readily Formed, Machined, Drawn, Molded or Welded

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SHEETS . . . $\frac{1}{32}$ " through 1". PIPE . . . $\frac{1}{2}$ " through 8" diameter (10 or 20 ft. lengths). ROUND BARS . . . $\frac{3}{8}$ " through 5" diameter (10 ft. lengths). WELDING ROD . . . $\frac{1}{8}$ " and $\frac{5}{32}$ " diameter.

TYPICAL APPLICATIONS

A rigid non-plasticized polyvinyl chloride, Van-Cor is fabricated into such products as: Ducts, Hoods, Chemical Tanks, Tank Liners, Plating Racks, Fume Stacks and Piping.

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Cleveland 4, Ohio

Provisions for Liaison—

(Continued From Page 8)

tention of forcing liaison on any unit committee but believes several committees will want to establish liaison with one or more other committees. By adding the above paragraph to the operation manual, it is hoped a uniform liaison method that will be both simple and workable has been established.

TABLE 1—Distribution of Plastic Pipe in Various Services According to Type, Size, Footage, and Number of Installations

TYPE OF SERVICE	SIZE OF PIPE													
	1¼-INCH		1½-INCH		2-INCH		3-INCH		4-INCH		5-INCH		TOTAL	
	No. of Installations	Total Footage	No. of Installations	Total Footage	No. of Installations	Total Footage	No. of Installations	Total Footage	No. of Installations	Total Footage	No. of Installations	Total Footage	No. of Installations	Footage
A. Butyrate Pipe														
Well Flow Line	1	3,000	..	....	28	34,821	3	5,051	..	....	..	....	32	42,872
Tank Battery Connections	13*	7,200*	1	100	..	....	..	....	1	100
Salt Water Gathering Line	1	5,000	7	26,111	5	10,133	2	4,100	..	....	15	45,344
Oil Gathering Line
Salt Water Disposal or Water Flood Injection Line	3	108	1	200	..	....	4	308
Gas Line
Total	1	3,000	1	5,000	35	60,932	12	15,392	3	4,300	..	....	52	88,624
B. Styrene Copolymer Pipe														
Well Flow Line	1	220	3	1,753	..	....	..	....	..	....	4	1,973
Tank Battery Connections	3	248	..	....	3	248
Salt Water Gathering Line	1	1,150	3	5,157	3	2,120	4	5,020	..	....	11	13,447
Oil Gathering Line
Salt Water Disposal or Water Flood Injection Line	1	700	..	....	..	....	1	5,500	2	6,200
Gas Line
Total	2	1,370	7	7,610	3	2,120	7	5,268	1	5,500	20	21,868

* These installations were reported as being in both flow line and tank battery service. They were not included in the total of 2-inch butyrate pipe.

Service Reports—

(Continued From Page 9)

pieces used in these lines. As explained in a more detailed manner later in the report, the questionnaire returns indicated these failures were primarily due to inadequate inspection or testing since many failures occurred within recommended operating levels. Most of the remaining failures were due to excessive operating stresses, selected by the operator, but based on strength data supplied by the manufacturer. With improved inspection and more reliable long-term strength data, plastic pipe could be installed with greater success in many oil field installations.

Plastic Pipe Materials

The questionnaire was designed to secure data on the various types of plastic pipe used in oil field operations. The one PVC pipe installation was of an experimental nature and being the only line of this material is reported individually at this point.

It consisted of 200 feet of 2-inch OD, 0.154-inch wall thickness pipe used in a well flow line operating at an average temperature of 110 F, which sometimes reaches a maximum of 120 F. The average operating pressure was 140 psi; the maximum pressure was 280 psi. Under these conditions the maximum calculated burst stress was 1820 psi. The installation failed after 20½ hours and was not repaired. The operator reported failure was due to mechanical fatigue and faulty extrusion. No explanation for the failure or evidence of faulty extrusion was reported.

The remainder of this report is concerned with the oil field experience with butyrate and styrene copolymer types of plastic pipe.

Type of Service

The information summarized in Table 1 shows the amount, size and number of installations in each service by type of plastic pipe. Eighty-six percent of the pipe used was 2, 3 and 4-inch size, with 2-inch the most common size, accounting

for 62 percent of the total pipe footage in 72 installations. No reports were received about plastic pipe in oil gathering or gas line service, although it is known that such installations have been made. No doubt reports on plastic pipe in this service could be obtained from oil pipe line and gas distribution companies.

Purpose of Installation

Plastic pipe usually is installed in oil fields as a means of controlling corrosion, paraffin or scale accumulations. Table 2 shows a distribution of the plas-

tic pipe covered by this survey according to the purpose of the installation. Approximately 70 percent (73,651 feet) of the plastic pipe covered by this survey was used to control corrosion. In this category, 15,400 feet of the pipe consisted of three 1.5 to 2-inch butyrate pipe installations which were inserted, as much as 1,500 feet at a time, into existing 2 and 3-inch steel lines.

About 33,000 feet or 30 percent of the pipe covered by this report was installed for paraffin control purposes. Although

(Continued on Page 12)

TABLE 2
Distribution of Plastic Pipe According to Purpose of Installation by Number of Installations, Pipe Material, and Total Pipe Footage

PURPOSE	Acetate Butyrate		Styrene Copolymer		Total	
	No. of Installations	Total Footage	No. of Installations	Total Footage	No. of Installations	Total Footage
Corrosion Control	23	53,356	17	20,295	40	73,651
Paraffin Control	26	33,745	1	220	27	33,965
Scale Control	2*	650*	..	..	..	..
Corrosion and Paraffin Control	1	873	2	1,353	3	2,226
Corrosion and Scale Control	2	650	..	..	2	650
Total	52	88,624	20	21,868	72	110,492

* One flow line and one tank battery connection installation reported as installed for both corrosion and scale control.

TABLE 3—Effect of Installation Technique on Failure of Plastic Pipe

INSTALLATION TECHNIQUE	Where Pipe Experienced Failure	Of These Total Installations	Per Cent Experiencing Failure
Number of Unburied Pipe Installations	2 ^a	11	18
Footage of Unburied Pipe	120	636	19
Number of Buried Pipe Installations	21	61	34
Footage of Buried Pipe	33,048	109,856	30
Number of Pipe Installations Relying on Slack Alone for Protection Against Thermal Expansion	18 ^b	41	44
Footage of Pipe in Above Installations	27,968	88,599	31
Number of Installations Equipped with Dresser Sleeves for Thermal Expansion	5 ^c	31	16
Footage of Pipe in Above Installations	5,200	21,983	24

^a Both installations were misapplications; one a stock-tank vent line, the other connected directly to a pump.

^b Six installations (15,265 feet) experienced failures due to either an excessive operating temperature (above 212 degrees F.), or pressures causing calculated burst stresses over 1200 psi.

^c Four of these failures (2200 feet of pipe) were due to too much clearance between pipe and slip sleeve collar. One remaining failure occurred at 120 degrees F., 200 psi burst pressure, which caused a calculated burst stress of 1470 psi on butyrate pipe.

* A switch rings wip at Norris Extremel were mai Installation

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NOTE: Firesto

How Exon 402-A wipes out corrosion

No corrosion in Kodak's cost picture ...since **Boltaron** 6200 was developed!

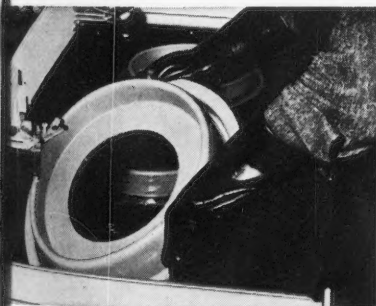
Bleach cells were doomed after ninety days of service at the Eastman Kodak processing laboratories. One material after another failed to survive corrosive ferricyanide.

In 1951, Kodak engineers installed a test cell of BOLTARON 6200. Three years later, it's still in use...hasn't been damaged! So convincing was this test that Kodak installed forty-nine more BOLTARON 6200 bleach cells...and wiped out corrosion costs!



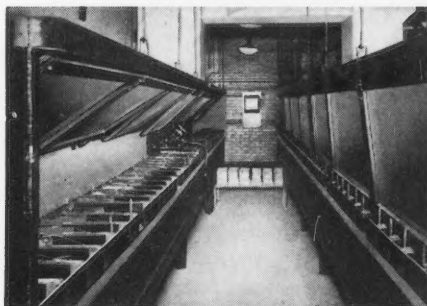
Installation by Industrial Plastic Fabricators, Inc.

Photographs courtesy H. N. Hartwell & Son, Inc., Boston 16, Mass.

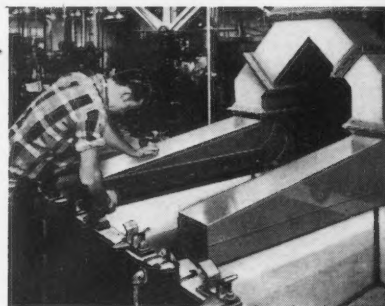


★ A switch to Boltaron 6200 copper-plating rings wiped out corrosion in this equipment at Norris-Thermador Co., Los Angeles. Extremely close tolerances were maintained.

Installation by Horace Blackman Co.



★ For 18 months, sulfuric acid fumes have failed to corrode a Boltaron fume removal system at Electric Storage Battery Company, Fairfield, Conn.



★ Maintenance costs were wiped out at Cannon Electric Co., Los Angeles. A metal-corroding solution of 33% nitric, 33% sulfuric acid and 33% fluoride salts has left Boltaron ducts and tanks unmarked for a year.

Installation by Horace Blackman Co.

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Chemical Sales Division

FIRESTONE PLASTICS COMPANY, DEPT. 27C, POTTSTOWN, PENNSYLVANIA

A DIVISION OF THE FIRESTONE TIRE & RUBBER CO.



NOTE: Firestone supplies the resin only, does not manufacture the end product.

Service Reports—

(Continued From Page 12)

to steam clean the line, whereupon failure occurred.

The third installation experiencing paraffin deposition consisted of 4100 feet of 2-inch butyrate pipe in well flow-line service. The operating temperature of this installation was not reported. However, the operator advised the line plugged once during the first year of service and that evidence noted at the time of inspecting the line indicated the paraffin plug may have formed in the adjoining steel line and was pressured over into the plastic pipe. No attempt was made to clean the line as it was severely plugged. At the time the line was abandoned, it had not experienced any failures.

The remaining 24 reports on extruded plastic pipe in paraffin control service did not give specific information concerning paraffin accumulations. In view of the lack of reports to the contrary, it is logical to assume that many of these installations have been satisfactory from a paraffin deposition viewpoint.

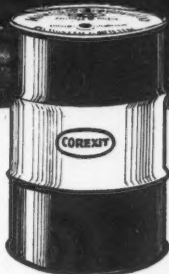
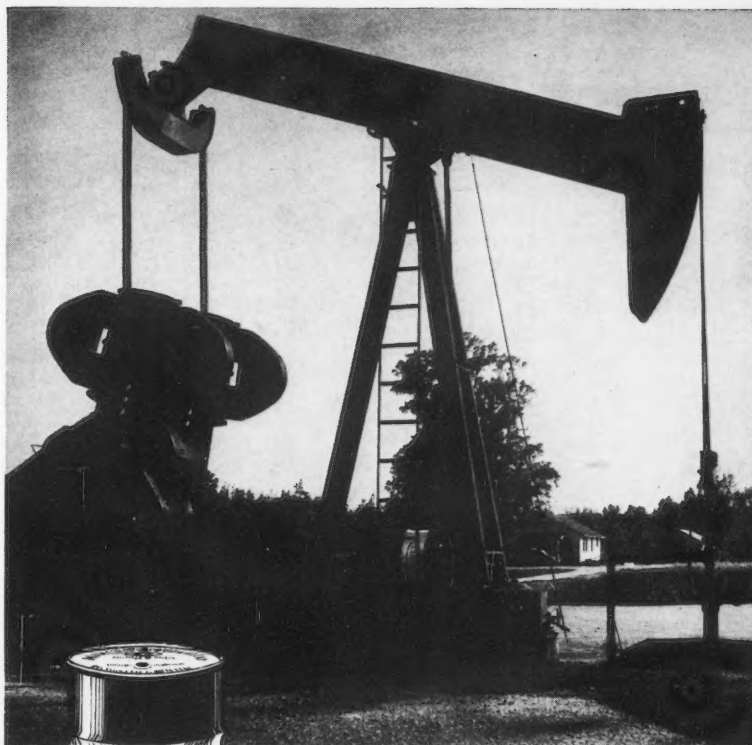
Method of Installation and Connections

With the exception of the PVC pipe, which was threaded, all other extruded plastic pipe installations used slip-sleeve cemented couplings. In making connections to steel pipe about 25 percent of the operators used Dresser couplings, while the remainder used plastic male adapters. Reported precautions against thermal expansion varied from none to the use of both Dresser couplings and laying the line slack in the ditch. About a fourth of the operators did not make provisions for thermal expansion, although several reports qualified this by stating that it applied to short lines only. One operator considered a 200-foot line as short, while another considered 500-feet as a short line.

As shown in Table 3, eleven of the 72 extruded plastic pipe installations were not buried. Three were serving as tank battery connecting lines and three were either in salt water disposal or water flood injection line service. None of these six experienced failure. Four unburied lines were serving in salt water gathering lines; of these, one line experienced failure due to vibration caused by a pump to which it was connected. Maximum pump pressure caused a calculated burst stress of 600 psi at 1000 degrees F which was within the recommended operating stress of this butyrate pipe. The one remaining unburied line was used as a tank battery vent line which elongated and sagged between supports. Although complete failure did not occur, the line was changed for appearance purposes.

Installations Experiencing Failures

Twenty-three of the 72 extruded plastic pipe installations (excluding the PVC pipe) covered by this survey experienced one or more failures. All but four of these failures were repaired and the systems returned to service. The survey did not attempt to determine the type of any corrective measures taken, but it can be assumed that most operators made changes necessary to avoid repetition of the failure. Although the portion of in-



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TABLE 4—Description of Failures Experienced in 23 Installations

Maximum Temperature °F.	Maximum Calculated Burst Stress PSI	Type of Service	DESCRIPTION OF FAILURE
110 110* 110	0 400* > 800	Stock Tank Vent Line Well Flow Line* Well Flow Line	A. Butyrate Pipe Ambient temperature caused pipe to elongate and sag between supports. Failures due to line leaks caused by too much clearance between the pipe and slip-sleeve couplings. Eight failures occurred in this line in seven months before replacing with steel. Four failures believed due to pressure surges above 100 psi (causing burst stress > 800 psi) and the other failures are believed due primarily to thermal expansion. (1100 feet—2 inch pipe snaked in ditch.) Pipe failed during first month of operation. Pipe connected to pump. Failure thought due to pump vibration. Pipe lost shape where laid on surface. Pipe failure due to excessive pressure which was unexplained. One collar cracked and one joint split on first day of operation. No further failures in 42 months. Eight joints split during the first month of operation. No subsequent failures for seventeen months. During 27 months of operation line failed once at plastic male adapter. Line consists of 950 feet of 2 inch pipe which was not fitted with Dresser sleeves. Failure reported as due to thermal expansion and mechanical load. Line consisted of 200 feet of 4 inch buried line not equipped with Dresser sleeve. Failure reported as due to faulty materials. Line failed once in 14 months when operator inadvertently closed valve causing unknown pressure. Line failed once in 15 months due to reported faulty joint. Line failed once during first year due to unexplained pressure surge of 200 psi (stress 1890 psi). One 45 degrees ell cracked along seam during 10 months service. Same as above. Line consisted of 3000 feet of 1½ inch buried pipe fitted with Dresser sleeves. An unreported number of failures attributed to thermal expansion and excessive pressure were experienced.
100 85 85 85 100	625 160 360 160 320	Salt Water Gathering Line Well Flow Line Well Flow Line Well Flow Line Well Flow Line	
100	170	Salt Water Disposal	
Not Reported Not Reported Not Reported	855 805 1890	Well Flow Line Well Flow Line Well Flow Line	
112 130 120	0 0 1470	Salt Water Gathering Line Salt Water Gathering Line Well Flow Line	
212	228	Well Flow Line	
100	1210	Salt Water Disposal	
120	620	Salt Water Disposal	
70 70	1500 550	Fresh Water Line Fresh Water Line	
			B. Styrene Copolymer Pipe Line, consisting of 220 feet of 1½ inch buried pipe laid without Dresser couplings, failed while attempting to steam paraffin out of line. Line consisted of 5500 feet of 5 inch buried pipe laid without Dresser sleeves. One failure in 14 months at abrupt change of direction where line pulled out of slip joint. Operator reported failure due to excessive pressure. Line consisted of 2000 feet of 3 inch buried pipe laid without Dresser couplings. In the first 14 months of operation the line failed several times under these conditions. Line consisted of 1000 feet of 4 inch buried pipe laid without Dresser sleeves. Line consisted of 1150 feet of 1½ inch buried pipe laid without Dresser sleeves. Both fresh water lines designed for maximum conditions. Several joint failures, which occurred in 5 months of operation, were reported by the operators as due to material failure.

* Represents conditions of four line installations reported by one operator. All four installations suffered same failures.

Service Reports—

(Continued From Page 13)

installations experiencing failure is relatively high, actual failure occurred to couplings and fittings used. However, since failure of one piece causes failure only 127 of about 11,000 pieces of pipe, of the whole line, it is important to determine the cause of that one failure if possible. The following sections of this report consider the various possible causes for these failures.

Effect of Installation Technique on Failure

In an effort to determine if the manner of installation might have played a role in the failures, Table 3 was prepared. Although burying of the line would seem to provide additional protection and increase the ability of plastic to withstand operating stresses, the data in Table 3 show a higher percentage of buried pipe experienced failure from both a footage and number of installations standpoint. However, the small amount of unburred pipe used for comparison might not be representative of actual experience. Table 3 indicates that Dresser sleeves may help reduce failures due to thermal stresses since the percentage of failures is lower for installations equipped in this manner than for those which relied entirely on "snaking" of the line in the ditch for protection from thermal expansion. Furthermore by disregarding failures due to excessive burst stresses (see notes b and c, Table 3), the data further indicates Dresser sleeves apparently provide some protection from failures caused by thermal expansion.

Effect of Operating Temperatures and Stresses on Failure

Figures 1 and 2 were prepared to

TABLE 5—Distribution of Plastic Pipe by Manufacturer, User, and Cause of Failure

	Number of Installations	Footage	CAUSE OF FAILURE		
			Misapplications	Excessive Temperature, Pressure, or Thermal Expansion	Material Failure
A. PIPE MANUFACTURER					
1. Butyrate					
A.....	16	27,941	1	4	2
B.....	3	108	..	..	..
C.....	4	2,200	..	..	4
D.....	2	6,180	1	..	..
E.....	1	4,700	..	..	..
F.....	15	10,900	..	..	1
G.....	11	36,595	..	2	3
	52	88,624	..	..	..
2. Styrene Copolymer					
X.....	10	7,445	..	1	1
Y.....	10	14,423	..	2	1
	20	21,868	2	9	12
B. USER					
A.....	43	62,170	1	5	8
B.....	4	1,208	..	1	..
C.....	3	7,511	..	..	..
D.....	10	22,370	1	1	1
E.....	6	13,666	..	1	2
F.....	2	1,141	..	1	..
G.....	3	2,226	..	..	..
H.....	1	200	..	..	1
	72	110,492	2	9	12

show the relationship between the operating stress and the 23 plastic pipe failures reported in this survey. These charts show the maximum temperature and the maximum calculated burst stress experienced in each installation. Although average and maximum operating temperature and pressure conditions of each installation were reported, only the maximum values have been plotted since plastic pipe installations must be designed for such service. The pipe manufacturer and reported cause for failure have been shown by symbols on these two charts. In addition, a line represent-

ing the calculated burst stress at the most conservative operating pressure recommended by the manufacturers is also shown. Since this line represents a recommended safe working stress, no failures due to stress should occur below this level. In fact, if this line represents a stress providing a safety factor of four or five, it should be possible to take advantage of the safety factor in some instances and stress these materials at a slightly higher level without failure.

For butyrate pipe, Figure 1 shows two

(Continued on Page 15)

Service Reports—

(Continued from Page 14)

installations below this line which reported failure due to excessive pressure. However, unless these installations were subject to pressure surges higher than the reported maximum operating pressure, it would be more appropriate to consider them the result of substandard pipe or fittings. As shown on Figure 1, 11 additional failures were reported below the recommended stress level line. Of these, the operators reported nine due to substandard pipe or fittings and two due to misapplication.

Seven installations of butyrate pipe were in service where the maximum temperature and stress levels were above the recommended level. Five of the seven installations experienced failure, although five installations were operating at less than 22 percent above the recommended stress level. The remaining two installations were stressed at less than half the reported tensile strength of acetate butyrate at this temperature. Four of the five failures were reported by the operators to be due to excessive pressure, although sufficient strength should have remained at these stress levels if the recommended operating pressure had actually provided a safety factor of four or five as claimed by some pipe manufacturers. Three of these installations have been retired due to continuing failures.

Figure 2 for styrene copolymer pipe reveals similar experience. Three of the five failures occurred at stresses below the recommended operating level which usually is reported by manufacturers as providing a safety factor of four. Two of these three failures were reported by the operators as due to substandard material. The third failure was reported due to excessive pressure which may be true considering the temperature. Although manufacturer's data indicate sufficient strength at that temperature the two installations which experienced failure when operating above the recommended stress level were stressed only to about one-half of the tensile strength of the material as reported by most manufacturers of styrene copolymer pipe. It is significant to note that none of the fifteen installations of styrene copolymer pipe operating below 230 psi burst stress experienced a failure.

An examination of all plastic pipe failures on a piece rather than complete installation basis reveals that only 18 of the 127 piece failures occurred above the operating stress recommended by the manufacturer. Two pieces failed because of misapplication such as the tank vent line and pump discharge line. The remainder, or 107 pieces, failed within the recommended operating range and must be assumed to be substandard production and inadequate joint strength either from an installation or fabrication standpoint. An adequate inspection and/or test might eliminate a considerable portion of such production and greatly reduce the failure frequency of plastic pipe in the field from both a piece and installation standpoint.

Cause of Failures

Although the cause of failure of the 23 plastic pipe installations which experienced such difficulties could not be definitely established in each case, most users were able to assign a reason for

the trouble. Table 4 itemizes the explanations for each failure and shows the maximum operating temperature and calculated burst stress to which each system was subjected. A breakdown of the cause of failure shows two installations (considered here as failure of 2 pieces) were probably improper applications such as a tank battery vent line and pump discharge line. Nine installations (18 pieces) suffered failures because of reported improper operation or installation.

Failures of this type were caused by accidental closing of a valve, unexplained pressure surges, or possibly to thermal expansion in long lines. The remaining 12 installation failures (107 pieces) were attributed by the users to substandard

pipe or fittings. However, in several cases the reports indicated that unrelieved stresses caused by thermal expansion, pressure surges and inadequately cemented couplings could have caused the failure. On the other hand, four installations (88 couplings) failed because of definite pipe deficiencies such as too much clearance between pipe and slip sleeve couplings and (37) pipe joints and fittings failed because of low strength and were in effect weeded out by failure during the first few hours or weeks of operation. Better inspection of pipe and fittings by the manufacturer would have materially improved this performance.

The data gathered were also examined
(Continued on Page 16)

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(Continued From Page 15)

to determine if failures were associated with any particular manufacturer or user. The thought in this case being that the fabrication or installation techniques peculiar to certain companies might influence the tendency for failure. As shown by Table 5, manufacturer C experienced failures in all four installations in which his pipe was used. The reason being excessive clearance between the pipe and slip sleeve coupling. Manufacturers A, F and G, who fabricated the pipe in about 80 percent of the installations experienced a failure frequency which might be indicative of different production techniques or plant testing of pipe before shipment. For example,

manufacturer F experienced only one material failure in 15 installations; whereas A experienced two material failures in 16 installations and manufacturer G, three failures in 11 installations.

Manufacturers of styrene copolymer pipe experienced approximately the same ratio of failures on a footage basis.

As for the influence of users on plastic pipe failures, Table 5 shows users A, D and E used almost 90 percent of the pipe and experienced about 80 percent of the failures which might be attributed to installation techniques having a tendency to cause failure of plastic pipe systems. Of the five plastic pipe systems experiencing pressure failure and installed by user A, three were actually designed for the high stress at which they failed. These three systems have

been replaced with steel. One of the remaining failures experienced by user A was due to accidental closing of a valve causing a high pressure. The other failure occurred when steam-cleaning a line to remove paraffin deposits.

In summary it appears that certain manufacturers have adopted quality control and/or pressure tests to eliminate low quality products or possibly use a production procedure conducive to higher quality product. These data also indicate that users apparently do not use installation techniques creating a tendency to cause failure but in a few cases have used relatively high design stresses, apparently with approval of the manufacturer, which have resulted in failure.

Failure Prevention Measures

In view of the experiences reported by this survey it appears several steps might be considered in the manufacture, installation and use of plastic pipe to reduce failures of oil field installations.

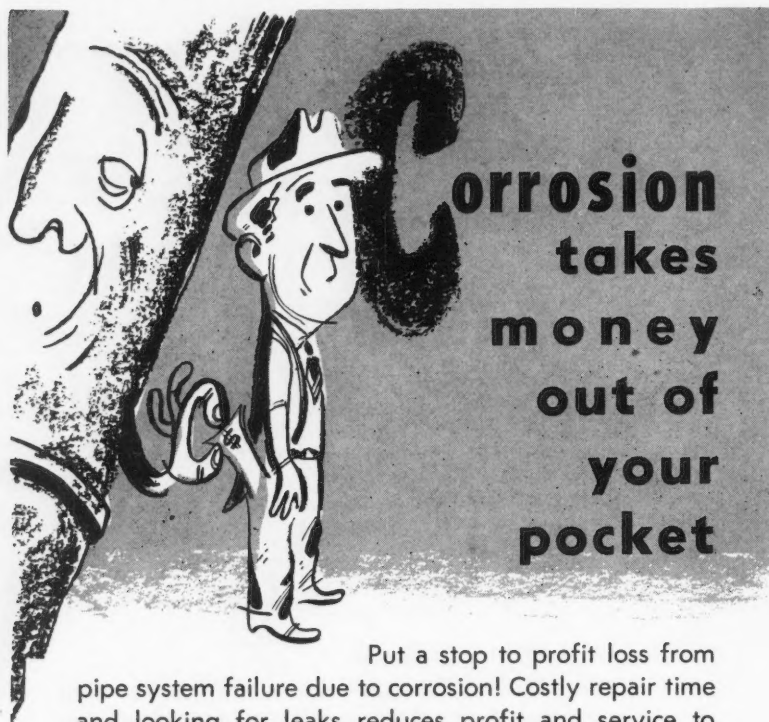
Failures of the type reported due to temporary excessive temperature or pressure could be avoided by the addition of shut-down or pressure-relief features set to protect the system. Although such features would probably change the economics of installing plastic pipe, many operators would probably be willing to consider the use of such provisions as a means to avoid failure. The use of Dresser sleeves at frequent intervals in lines operating at relatively high temperatures and pressures for plastic pipe, may tend to reduce stresses caused by thermal expansion which were considered the cause of failure by several operators.

In addition, it would be desirable if the operating temperature and pressure, together with the long-term strength of plastic could be carefully analyzed so each system could be designed and equipped with controls to operate at a safe stress level with an adequate and reliable safety factor. Such a design can, of course, only be accomplished with reliable information supplied by each manufacturer on the long-term strength of each product. The data in C. A. Levinson's report in the minutes of this subcommittee's last meeting are an example of the type information needed.

Short-term quality control tests, which correlate with long-term strength, are also needed by the manufacturer as a means of constant control over the quality of a given product. Results of this survey also indicate many plastic pipe failures could probably be eliminated by pressure tests run in the plant prior to shipment. However, the test pressure must be determined from known long-term strength data so it can be set high enough to actually be a test and yet be brief enough to be economical for the manufacturer and to have meaning for the user.

Film Available on Steel Centrifugally Spun Tubes

A 16-mm motion picture in sound and color titled "Acipco Steel Centrifugally Spun Tubes," describes the company's operations from the receipt of the basic materials to the shipment of the completed pipes. Copies are available for showing without charge from American Cast Iron Pipe Co., P. O. Box 2603, Birmingham 2, Ala.



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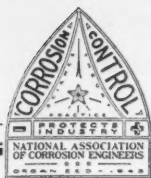
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General News

Chicago Technical Program Schedule Is Outlined



SCENES AT THE MASSACHUSETTS Institute of Technology Short Course June 21-25. Above, the refreshment stand located between the two laboratories was popular. Left, Frederick R. Meyer, Southern Bell Telephone Co., and R. M. Burns, in deep thought during the Duxbury clambake.

Three Thickness Gauges Developed by NBS

Three types of instruments for measuring the thickness of electrodeposited coatings have been developed by the National Bureau of Standards. They depend on the difference between the electrical conductivity of the plating and the basis metal but each makes use of different methods for sensing the resistance. Two of the instruments, the Dermatron and the Phase-Angle Thickness Meter use electromagnetic coupling to the specimen using the reflected field from eddy currents induced in the specimen; the third, a wave guide inspection tool employs direct conductivity measurement with point electrodes. Properly calibrated they may be used for calibration of magnetic as well as non-magnetic materials.

Low Nuclear Absorption Ceramics Developed

Boron-free coatings of the frit refractory type in which high-barium frit is combined with ceria-chromium oxides have been developed for use in protecting alloys in nuclear reactors by the National Bureau of Standards. The ceramics are satisfactory to withstand temperatures in excess of 1000 degrees C and have low nuclear absorption coefficients.

In 9 years Corrosion's Technical Section pages numbered more than 3000.

Eighteen Events Are Included in 1955 Eleventh Conference

Titles of eleven symposia to be held during the Eleventh Annual Conference and Exhibition of the National Association of Corrosion Engineers have been listed by H. L. Bilhartz, Production Profits, Inc., Dallas, technical program chairman. Also scheduled to be held during the March 7-11, 1955, meeting at Chicago are a panel discussion on pipelines, a pipe line problem clinic and an underground corrosion round table; a general corrosion problems round table, three educational lectures and numerous technical committee meetings. First day of the conference will be devoted wholly to committee meetings.

The chemical industry and petroleum production metallurgy symposia each will be divided into two sessions.

The annual business meeting of NACE, according to custom, will be the opening event of Tuesday, March 8. The technical events start when the business meeting ends and continue through noon Friday, March 11.

All meetings as well as the corrosion exhibition will be at the headquarters hotel, Palmer House.

Events in the technical program have been arranged as follows:

Tuesday, March 8

8:45 am—General business meeting.

10:15 am—Corrosion Principles Symposium. T. P. May, The International Nickel Co., Inc., New York, chairman; R. B. Hoxeng, United States Steel Corp., Pittsburgh, vice-chairman.

2 pm—Refinery Industry Symposium. F. M. Watkins, Sinclair Research Laboratories, Harvey, Ill., chairman; R. J. Hafsten, Standard Oil Co. (Indiana), Whiting, Ind., co-chairman.

2 pm—Oil and Gas Production Symposium. E. C. Greco, United Gas Corp., Shreveport, La., chairman; W. F. Oxford, Sun Oil Co., Beaumont, Texas; co-chairman.

4:30 pm—Education Lecture No. 1. Leonard W. Hartkemeier, Colorado School of Mines, Golden, chairman; F. H. Beck, Franklin H. Beck, Ohio State University, Columbus.

Wednesday, March 9

9 am—Chemical Industry Symposium—First Session. William B. De Long, E. I. du Pont de Nemours & Co., Wilmington, Del., chairman; J. J. Heger,

(Continued on Page 18)

85 Attend Short Course At MIT June 21-26

The corrosion short course at Massachusetts Institute of Technology, June 21-26 attracted some 85 registrants.

Following are some of the topics presented: Fundamentals of Corrosion Reactions and Control, Fundamentals of Tarnish and Oxidation, Treatment of Environment, Introduction to Selection of Metals and Alloys, Fundamentals of Cathodic Protection, Practice of Cathodic Protection, Metallic Coatings, Organic Coatings, Designing to Prevent Corrosion, Principles and Practices of Corrosion Testing.

The course was climaxed by a trip to the Wm. F. Clapp Laboratories, Duxbury, Massachusetts which was followed by a lecture on fouling and a clambake.

Hot Dip Galvanizers

The American Hot Dip Galvanizers Association, Inc. will meet September 16-17 at Hotel Dennis, Atlantic City for its 1954 semi-annual meeting.



★ **HOT DOPE** Straight from the Kettle on PIPE PROTECTION

★
By Boyd Mayes

Ever think about how specialized everything's gettin' to be? One doctor helps get the baby born, and right there he quits. You gotta get another specialist to keep the kid going. One mechanic works on your automobile brakes and sends you around the corner to get the radiator leak mended. Try gettin' your house fixed and the brick man won't touch the boards. If it keeps up the present trend you may some day have to have a separate painter for each color. Specialization is really not new. In the frontier days of West Texas the cow man was always takin' pot-shots at the neighbor who raised sheep. We got our idea of specialization as a kid back in the Piney Woods when we found that a coon dog that would mess with a skunk wasn't worth shootin'. There's a special way to split a stick, too, if you want to put a possum's tail in the crack. Specialization's a good thing, and we're all for it. We live by it. We specialize in the pipe line business, and we go further than that. We're almost in the same category as the foot doctor who won't work on nothin' but left big toes. We don't make pipe, don't bend it, don't dig ditches for it, don't string it nor lay it. We don't make pipe winches, booms, cradles, saddles, Holiday detectors or any other pipe line accessories. We just protect pipe for long life, trouble-free service by cleaning, priming, coating and wrapping it. At that, we admit we're good. We've been doing this specialized job for more than a quarter century. The woods are full of our satisfied customers, but we could still use some more.

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Conditions Existing at Time of Fatal Titanium Explosion Are Given

The following information has been received from Director J. J. Forbes, United States Department of the Interior, Bureau of Mines, Washington, concerning the explosion at College Park, Maryland in which one person died and another was severely injured while experimenting with titanium and red fuming nitric acid. The director also said findings of the committees investigating the explosion would be made available for publication as soon as completed.

On December 29, 1953, twenty-four flasks containing a total of 118 titanium specimens and six liters of red fuming nitric acid exploded, apparently all at once, in the face of the chemist who was manipulating the apparatus. The titanium involved in this accident was all commercially pure but of two types with respect to impurity content. One group of specimens contained the following impurities: 0.2% carbon, 0.4% iron, 0.02% manganese, 0.02% nitrogen and 0.005% magnesium. The second group contained only 0.05% carbon and 0.1% iron and the same percentages of the minor impurities. Most of the specimens consisted of two pieces of metal spot welded together, only eight were single. The specimens had been hot rolled or cold rolled to various degrees before spot welding; some of the specimens were stress relieved after spot welding. All of the specimens had sheared edges, some also had rolled edges. The flasks were stoppered in such a manner that they could be vented and this was done at regular intervals. The experiment was being carried out at room temperature and at the time of the explosion some of the specimens had been exposed for seven days while others had only been immersed the previous day. The nitric acid contained 20 percent dissolved oxides (NO₂). The explosion occurred while the attending chemist was venting the flasks. Apparently the reaction was triggered by a slight movement or jarring of one or more of the specimens.

The chemist who was working with the specimens was severely injured. Another person who came to his rescue died about a month after the accident as a result of inhaling nitric acid fumes.

Safety Device for Tests Involving Hydrogen Made

A means of purging with helium laboratory lines containing hydrogen gas used in experiments in heat treating and brazing has been developed by the National Bureau of Standards. The hydrogen gas presents an explosion hazard when 7 to 73 percent of the mixture is hydrogen and the balance air and the temperature is 500 to 600 degrees C. The valve to the helium container is set from 10 to 20 pounds lower than the normal pressure of the hydrogen line. If the hydrogen pressure drops the helium sweeps the line and prevents the dangerous mixture from forming.

Discussions and comments on material in Corrosion's Technical Section are welcomed for review prior to publication.

AISE Sessions Set at Cleveland Sept. 28-Oct. 1

Among the 48 technical papers to be presented during the exposition and convention of the Association of Iron and Steel Engineers in Cleveland September 28-October 1 will be:

September 28—Mechanical Session. How and why to reuse industrial cooling water.

September 29—Lubrication session. Stability of lubricating greases.

September 30—Protective Coating Session. Painting in the iron and steel industry. Protective coatings in coking plant areas. Operating practice session. Progress and applications in the use of titanium.

Chicago Technical—

(Continued From Page 17)

United States Steel Corp., Pittsburgh, co-chairman.

9 am—Pipe Line General Symposium, J. N. Hunter, Jr., Service Pipe Line Co., Tulsa, Okla., chairman.

9 am—Petroleum Production Metallurgy—First Session. Frederick J. Radd, Continental Oil Company, Ponca City, Okla., chairman; F. L. Current, Oil Well Supply Co., Oil City, Pa., co-chairman.

2 pm—Chemical Industry Symposium—Second Session.

2 pm—Power and Communications Industry Symposium. Lawrence O. McCormick, Consolidated Gas, Electric Light and Power Co., Baltimore, chairman; T. J. Maitland, American Telephone and Telegraph Co., New York City, co-chairman.

4:30 pm—Educational Lecture No. 2.

4:30 pm—Petroleum Production Metallurgy—Second Session.

Thursday, March 10

9 am—Cathodic Protection Symposium. Francis W. Ringer, Narberth, Pa., chairman; John C. Howell, Public Service Electric and Gas Co., Maplewood, N. J., co-chairman.

9 am—High Purity Water Symposium. D. J. DePaul, Westinghouse Electric Corp., Pittsburgh, chairman; A. H. Roebuck, Argonne National Laboratory, Lemont, Ill., co-chairman.

2 pm—Elevated Temperature Symposium. The International Nickel Co., Inc., New York City, chairman; C. C. Harvey, Ethyl Corp., Baton Rouge, La., co-chairman.

2 pm—Pipe Line Problem Clinic. R. L. Bullock, Interstate Oil Pipe Line Co., Shreveport, La., chairman; Lyle Sheppard, Shell Pipe Line Corp., Houston, co-chairman.

2 pm—Protective Coating Symposium. W. B. Meyer, St. Louis Metallizing Co., St. Louis, chairman.

4:30 pm—Educational Lecture No. 3.

Friday, March 11

9 am—General Corrosion Round Table. A. O. Fisher, Monsanto Chemical Co., St. Louis, chairman; F. N. Alquist, Dow Chemical Company, Midland, Mich., co-chairman.

9 am—Pipe Line and Underground Corrosion Round Table. Jack P. Barrett, Stanolind Oil and Gas Co., Tulsa, chairman.

Some Instrument Congress Technical Papers Have Corrosion Connection

Some of the technical papers to be presented during the First International Instrument Congress and Exposition at Commercial Museum and Convention Hall, Philadelphia September 13-24 by the Instrument Society of America are: Microscopy of Toxic Dusts by Germain Crossman, Bausch & Lomb Optical Co., Rochester.

Thickness Gauge for Dielectric Materials by W. W. Woods.

A Continuous Analyzer for Oxygen in Trace Quantities by Louis Thayer and Michael Czucha, A. O. Beckman, Inc., Pasadena, Cal.

An Instrument for Continuous Determination of Dissolved Oxygen Based on Paramagnetism by Alfred D. Robinson and Louis Thayer, A. O. Beckman, Inc.

The Use of X-Ray Diffraction in the Determination of the Physical Properties of Solids by Thomas L. Thourson, International Harvester Co., Chicago.

Review of Sonic Methods of Determining Mechanical Properties of Solids by C. E. Kesler, University of Illinois, Urbana.

Fillets Without Stress Concentration by Robert Lessard, Laboratoires des Automobiles Peugeot, Montbéliard, Doubs, France.

The Modern Stage of Non-Destructive Testing and Research Work by X-Rays by Richard Seifert, Richard Seifert & Co., Hamburg, Germany.

Flue Gas Sampling for Controlled Combustion by Robert S. King, Corn Products Refining Co., Chicago.

Use of Mass Spectrometer in Analyzing Exhaust Gases by H. Landsberg, Consolidated Engineering Corp., Pasadena, Cal.

An Investigation of the Dynamic Properties of Plastics and Rubberlike Materials by R. A. Eubank, Illinois Institute of Technology, Chicago; D. Muster, General Electric Co., Schenectady, N. Y.; E. G. Volterra, Rensselaer Polytechnic Institute, Troy, N. Y.

Aluminum Wrought Alloy Designations Changed

A new system of alloy designations for wrought aluminum and aluminum alloys has been adopted by the Aluminum Association and is scheduled to be effective October 1, 1954. Temper designations in effect since 1947 are being continued without change and will follow alloy designations.

The new system consists of 4-digit numbers and is expected to meet all future needs for designations for wrought alloys. First digit indicates the general group, the last two identify the alloy or indicate the aluminum purity while the second digit indicates any modifications of the original alloy or impurity limits.

A booklet "The Aluminum Association Alloy Designation System for Wrought Aluminum" is available from The Aluminum Association, 420 Lexington Ave., New York City.

Abstracts published in the NACE Abstract Punch Card Service come from more than 500 periodicals all over the world. Coding by topic, journal, author and year is provided.

The ATLAS DIRECTORY

of CORROSION PROOF CONSTRUCTION MATERIALS*

CORROSION PROOF CEMENTS

ALKOR—A furfural alcohol resin cement which is the nearest approach to a universal corrosion resistant cement. Complete resistance to non-oxidizing acids, alkalis, salts and most solvents at temperatures up to 380° F.

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CORROSION PROOF LININGS

ATLASTAVON—Polyvinyl chloride sheet lining resistant to acids, alkalis and some solvents.

SARAN SHEET—General purpose tank lining with excellent resistant properties.

NEOPRENE SHEET—Synthetic rubber lining resistant to water solutions of non-oxidizing acids, salts and alkalis, exhibiting excellent resistance to abrasions.

CORROSION PROOF COATINGS

NEOBON—High build neoprene coating especially suitable for application to varied shapes, can be sprayed or brushed. Recommended for splash and fume protection.

NEELIUM—Exceptionally high build neoprene base coating for obtaining 15-20 mils. thickness per coat.

ZEROK SERIES—A complete series including vinyl chlorinated rubber and styrene butadiene copolymer based coatings. Black, white and gray.

IMPERVIOUS MEMBRANES

ATLASTISEAL—A hot melt three layer system lining used behind brick for protecting concrete tanks against corrosion of water solutions of non-oxidizing acids and salts.

INDUSTRIAL FLOORS

ATLAS ACID-ALKALI-SOLVENT-GREASE PROOF FLOORS—composed of an impervious flexible membrane and acid proof brick joined with corrosion proof cement. These floors have been solving industry's floor problems for over a quarter century.

FURNACE FLOORS

FOOD INDUSTRY FLOORS—A dual cement floor construction especially designed for use in food processing plants and biological laboratories.

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A complete line of rigid fabrications built to specifications for exhaust systems, duct, process equipment, tanks and liners made from the plastic best suited for the requirement of the structure. Pipe of standard size available.

FOR FURTHER INFORMATION, CLIP THIS AD, CHECK PRODUCTS OF INTEREST AND MAIL.

*Trade names reg. U. S. Pat. Office. Alkor, Vitrobond, Carbo-Korez, Atlastavon, Neobon, Neelium, Zerok, Furnace.



ATLAS MINERAL PRODUCTS CO.

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BOOK REVIEWS

Rare Metals Handbook. 657 pages, 6 x 9 inches, hard cloth, 1954. Clifford A. Hampel, editor. Reinhold Publishing Corp., 330 West 42nd St., New York 36, N. Y. Per copy, \$12.00.

From alkaline earths to zirconium, this collection of data by numerous experts on the materials discussed provides specific information for the metallurgist and worker who needs factual data on these metals. Emphasis is on the metallic or elemental form of the metals discussed. Significant are the numerous references appended to each chapter which number in one case (uranium) 289. Other chapters are referenced proportionately.

There is a subject index.

Mededeling No. 27. Rapport van Corrosie Commissie II Voor de Bestudering van Buisaantasting Door Bodeminvloeden. (In Dutch) 110 pages 6 x 8 1/4 inches, paper cover. April, 1954. Corrosie-Instituut T.N.O., Postbus 49, Delft, Holland. Price not indicated.

This is a report on tests started in 1938 to determine the aggressiveness of certain soils against cast iron and steel. Eighteen pieces eight of 4-inch pipe made of centrifugal cast iron, as cast; centrifugal cast iron with the skin turned off; steel, with mill scale and steel pickled in phosphoric acid were buried in six different types of soil. Every two years three specimens of each tube are removed from each site and examined. Pitting, loss of weight, chemical compo-

sition of the soil and corrosion products are determined.

Conclusions reached so far indicate the skin of the cast iron pipes is protective in active sulfate reduction soils, giving them longer life than the steel pipes; the skin was not as protective in acid soils, but the corrosion of cast iron was less than that of steel; mill scale is harmful in soils actively reductive but not in sandy soils; calcareous sand or marl backfill reduces corrosion in acid soils but has little effect in sulfate reducing soils.

Corrosion of all samples was severe in active reducing soils, heavy in acid soils and least in sandy soils. In sulfate soils the corrosion products do not form a crust on the surface of the tube; in aerobic soils the crusts are of the sandy type; in acid soils they are red rust on the outside with some iron sulfide near the surface of the tubes.

Extensive tables of analyses of the corrosion products, pitting and soils are included.

Stainless Steel Handbook. 120 pages, 7 1/2 x 10 1/2 inches, cloth, 1951. Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh, Pa. Free.

The principal types of stainless steel produced by Allegheny Ludlum are itemized and described as to mechanical properties, analyses, physical data, electrical properties, etc. The tabulated information also indicates tempering and drawing temperatures, creep strength and other data.

An alphabetical tabulated list of corrosives, including organic natural compounds such as tomato juice and glycerin is rated against four principal classes of forged steel according to recommended use with the corrosive. Extensive tabulated data are provided also on analyses, with texts detailing the resistance to corrosion of the principal types of stainless produced by the company.

Similar information is provided on cast stainless steels.

Low temperature properties are discussed and in a section devoted to fabrication, the text deals with the various ways by which the metals may be formed, joined and machined.

Tables of physical dimensions of standard sizes of bars and sheets, wire, clad plates, tubes, circles, gages; conversion tables, formulae for measurements, hardness conversion tables are included also. There is an alphabetical subject index.

Corrosion Data Survey. 1954 Edition. 8 1/2 x 11 inches. Cloth. Compiled by G. A. Nelson. Shell Development Company, Emeryville, Cal. Per copy, \$35.00.

A vast amount of information on the effect of corrosives against commonly used materials of construction in chemical plants has been collected into usable form in this book. The principal content is 60 corrosion data charts measuring 15 by 10 inches in which the corrosion characteristics of the materials considered are recorded in some detail. Data reported are taken from 20 sources, some periodicals and other books, pamphlets and collections of printed information.

The 28 materials considered are used as the horizontal ordinate of the charts, while an alphabetical list of corrosives comprises the vertical ordinate. The intersection of the ordinates consists of an

(Continued on Page 21)

VIBRA-PAK ANODES

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Corrosion engineers tell their own story how VIBRA-PAK anodes successfully lessen corrosion on submerged or buried metal structures. Here is an authentic case history, from the files of a major company telling how VIBRA-PAK anodes effectively and economically reduced installation cost on a 60 mile section of pipeline.

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area ruled into 100 squares. This permits the recording of the following information: 1) Concentration in aqueous solutions and ratings for dry materials; 2) temperatures in 50 degree increments from 75 to 300 degrees F and up to 800 degrees in 100 degree increments. Higher temperature data is also indicated when significant; 3) Four ratings of corrosion based on dimensional loss per year. Important information on velocities, impurities, aeration, surface condition and galvanic effects is added also in small notes added to the graphs. Small notes also have been added on factors related to fabrication and heat treatment but inhibitors are not considered.

The data presented are suggested to permit rapid elimination of unsuitable materials but are not recommended as a final basis of choice in every instance.

A column devoted to special alloys includes ratings of materials such as zirconium, titanium, Stellite, Illium G, Chlorimet, and others. Non-metallics considered include Haveg, Saran, Teflon and Karbate.

The final series of charts considers corrosion of materials by sulfuric, hydrochloric, mixed acids, hydrogen and carbon monoxide with the ordinates respectively temperature and concentration in percent. Area effects indicate the data.

The book concludes with a section devoted to the comments of research laboratories to which copies of the earlier book (1950) were sent.

Petroleum Microbiology. 375 pages, 6 x 9 inches, 1954. By Ernest Beerstecher, Jr., Elsevier Press, Houston. Per copy, \$8.00.

While much of the material in this book is related to the geological aspects of microbiology as it pertains to petroleum technology, significant portions pertain to the biological characteristics of such items as drilling mud and activities of microorganisms in petroliferous structures. For example a discussion of the effect of sulfur bacteria and algae in formations, the effect of iron bacteria and the effect of sulfate reducing bacteria in Chapter 7 is likely to include information significant to the corrosion engineer.

Chapter 8 titled The Role of Microorganisms in Corrosion covers theoretical considerations, aerobic and anaerobic organisms, bacterial corrosion in petroleum engineering, microbial deterioration of nonmetallic oilfield equipment and ends with references.

There is a glossary, author index, microorganism index and subject. As usual with Elsevier publications, typography and printing are superior.

Industrial Inorganic Analysis. 368 pages, 5½ x 8½ inches, 1953. Chapman & Hall Ltd., London. John Wiley & Sons, 440 Fourth Ave. New York 16, N. Y. Per copy, 36s.

Forty-one elements, principally metals, with additional chapters on miscellaneous analyses and data, determining acidity of special samples, gas analysis, water, zanthates are covered in this work. It is designed to supply the methods, reasons for and certain techniques which are useful to the industrial chemist in analysis. Each chapter ends with a list of references to the methods given and there is, in addition, a bibliographic section, an author and alphabetical subject index.

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Inter Society Corrosion Committee

CORROSION MEETINGS CALENDAR

Nov.

- 1-3 American Institute of Mining and Metallurgical Engineers, Institute of Metals Division, Fall Meeting, Sheraton Hotel, Chicago, Ill.
1-5 National Metal Exposition, Chicago, Ill.
8-11 American Petroleum Institute, Conrad Hilton Hotel, Chicago, Ill.
14-18 National Association of Corrosion Engineers, Western Regional Division meeting, Los Angeles, California.

- 15-18 American Gas Association, Operating Section, Organization Meetings, Hotel New Yorker, New York.
28-Dec. 1 American Society of Refrigerating Engineers (50th Annual Meeting), Hotel Ben Franklin, Philadelphia, Pennsylvania.

- 28-Dec. 3 American Society of Mechanical Engineers (Annual Meeting), Hotel Statler, New York, New York.

Dec.

- 12-15 American Institute of Chemical Engineers (Annual Meeting), Statler Hotel, New York, New York.

1955

Feb.

- 16-18 National Association of Corro-

- sion Engineers (Sixth Annual Pipeliners Short Course) Mayo Hotel, Tulsa, Oklahoma.

March

- 7-11 National Association of Corrosion Engineers, Annual Conference & Exhibition, Palmer House, Chicago, Ill.
28-April 1, 9th Western Metal Congress and Exposition, Pan-Pacific Auditorium, Los Angeles, California.

May

- 1-14 American Institute of Chemical Engineers, Shamrock Hotel, Houston, Texas.
9-13 A.G.A. Industrial Gas School—(location to be announced).
16-18 Southern Gas Association, New Orleans, Louisiana.

June

- 5-9 Canadian Gas Association, Annual Meeting, General Brock Hotel, Niagara Falls, Ontario, Canada.
12-17 American Water Works Association Annual Conference, Chicago, Illinois.
13-18 American Society of Mechanical Engineers (75th Anniversary Meeting), Congress and Hilton Hotels, Chicago, Illinois.

Oct.

- 17-19 A.G.A. Annual Convention, Los Angeles, California
17-21 National Metal Exposition, Detroit, Michigan (A.G.A. will exhibit).

Nov.

- 13-18 The American Society of Mechanical Engineers, Congress & Hilton Hotels, Chicago, Illinois.
27-30 American Institute of Chemical Engineers (Annual Meeting), Statler Hotel, Detroit, Michigan.

1956

March

- 12-16 National Association of Corrosion Engineers, Annual Conference & Exhibition, Hotel Statler, N. Y., New York.

Oct.

- 15-16 National Metal Exposition, Philadelphia, Pa. (A.G.A. will exhibit).
29 to Nov. 1 A.G.A. Annual Convention, Atlantic City, New Jersey.

Nov.

- 25-30 The American Society of Mechanical Engineers, Statler Hotel, New York, New York.

1957

Oct.

- 21-25 National Metal Exposition, Cleveland, Ohio (A.G.A. will exhibit).

New Laboratory Opened

A new surface technology research laboratory has been opened in the Research Division of New York University's College of Engineering. The research staff is under Dr. Max Kronstein.



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For a period of 12 years the Nelson Electric Manufacturing Company has been furnishing Phenolic Insulating Materials for pipe nipples and the insulation of pipeline flanges. We introduced the use of thin-wall tubing sleeves for insulating the studs in standard flanges, without requiring re-drilling of the flange and providing smaller studs. We now offer flange insulation, packaged for immediate shipment on the more common sizes.

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NEW PRODUCTS — Materials — Service — Literature

A Joint Release of the American Society for Testing Materials and American Welding Society is Tentative Specifications for Corrosion Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes. The bulletin is available at 25c per copy from American Society for Testing Materials, 1916 Race St., Philadelphia, Penn., and The American Welding Society, 33 West 39th St., New York, N. Y.

Weaver Engineering and Supply Co. has opened new main offices and warehouse at 718 West Main St., Grand Prairie, Texas. The company's Houston office is located at 4135 Southwestern St.

Koroseal linings are applied to tanks in the Ames, Iowa area by Tank Linings, Inc., 923 Second St., Ames, Iowa.

Protective Coating Engineering and Inspection Service has opened offices at 4101 San Jacinto St., Houston. A complete engineering service for coatings will be provided.

Reilly Tar and Chemical Corp. has opened an office in Houston at 2009 Fannin St. Donald Becker is in charge.

The Chemical and Metallurgical Division of General Electric Company, recently organized, includes the former chemical division and Carbonyl department.

R-500 Resistoflex hose manufactured by Resistoflex Corp., Belleville, N. J. handles hydrogen peroxide and white fuming nitric acid in rocket engines without any deleterious effects, the company reports. It is made from fluorocarbon resins.

TK-202, a flexible polyethylene pipe and **TK-404** a semi-rigid cellulose acetate butyrate pipe are now being produced by Tube-Kote, Inc., Houston. The company plans to make other types of plastic pipe. Literature on these new products are available on request from the company, P. O. Box 20037, Houston 25, Texas.

Zytel nylon resin molding power is said by the Polychemical Department of the DuPont Company to be resistant to ultraviolet degradation.

Facts About Zirconium, a 64-page booklet available from the Corborundum Metals Co., Inc., Niagara Falls, N. Y. describes the history and production of zirconium, its mechanical and physical properties, fabrication details, and considers compounds of the material such as zirconium tetrachloride, dioxide.

Roxon Volumaire Model R200 spray equipment is recommended by the manufacturer for application of all manner of liquids and slurries. Hot and cold spraying with a large volume of air permits the use of the spray gun with extremely viscous and colloid suspension materials.

Monel wire mesh demister pads inter-

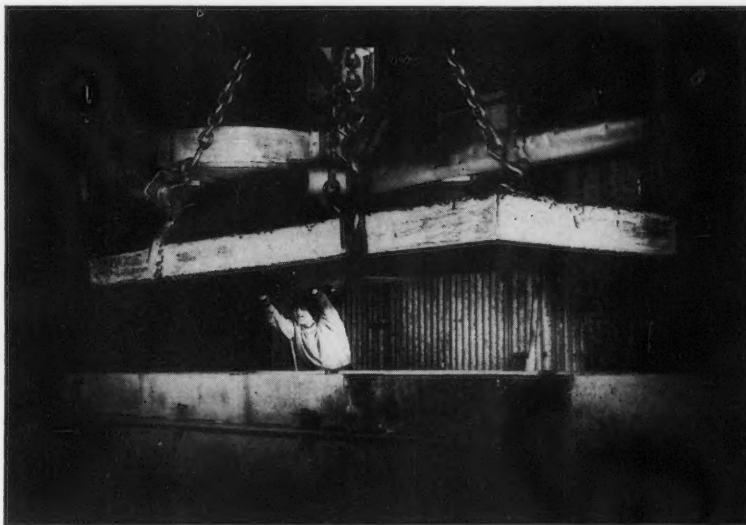
cepted a finely divided caustic spray from the top of a scrubbing tower and eliminated a serious air pollution problem, according to Otto H. York Co., Inc., 69 Glenwood Place, East Orange, N. J. Copies of the case history on the installation are available.

Zincoater, a two-part coating composed of metallic zinc dust and a phenolic resin vehicle and tung oil, adheres to galvanized surfaces and may be covered with enamels or other paints. The material is made by The Tropical Paint and Oil Co., Cleveland 2, Ohio.

Dynel covered paint rollers developed by Gates Engineering Co., cut application time of coatings in half and are highly resistant to strong chemical solvents used in cleaning them.

Teflon bellows are available with companion flanges conforming to American Standard bolt hole circles and numbers for pressure up to 125 psi for any size pipe from ½ through 12 inches. Crane Packing Co., 1800 Cuyler Ave., Chicago 13, is manufacturer. Information can be secured also from Crane Packing Co.,

(Continued on Page 24)



Subject: lead sheet and pipe

You may say that lead pipe and lead sheet are pretty much alike no matter who makes them or from whom you buy them. "Pretty much alike" is right. But not exactly alike. Here's why . . .

Federated's experience in lead production and in lead research means that you profit two ways when you buy corrosion-resisting lead pipe, sheet, valves or fittings from Federated: You get a product that is *certain* to be as good as any other . . . and probably better . . . and you get the *best technical help* with your problem.

For any information on the use of lead, write to Federated's *Corrosion Advisory Service*. Address the main office (below) or any one of Federated's 14 plants and 24 sales offices across the nation.

Federated Metals Division

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In Canada: Federated Metals Canada, Ltd., Toronto and Montreal

Aluminum, Magnesium, Babbitts, Brass, Bronze, Anodes, Zinc Dust,
Die Casting Metals, Lead and Lead Products, Solders, Type Metals



NEW PRODUCTS

(Continued From Page 23)

Ltd., 617 Parkdale Ave. North, Hamilton, Ont.

Novel Applications of asphalt coatings are detailed in Booklet GM-100 available from Insul-Mastic Corp. of America, 1141 Oliver Bldg., Pittsburgh 22, Pa.

Jet Engine rotor forgings and other unfinished engine parts are automatically inspected by ultrasonic waves by a machine developed by Sperry Products, Inc., Danbury, Conn. for Allison Division, General Motors Corp.

Jones & Laughlin Corporation's new \$1,500,000 research center will be constructed on Baldwin Hill overlooking the company's Monongohela Works.

High Vacuum Furnaces, Their Use and Application, a brochure, is available from F. J. Stokes Machine Co., 5500 Tabor Road, Philadelphia 20, Pa.

Acco Aluminized steel coated wire is available from Page Steel and Wire Division, American Chain and Cable Co., Monessen, Pa. The wire is coated by a new hot dip process. Types available include: 7-wire strand in Siemens-Martin, High Strength and Utility. Based on a coating of zinc of equal thickness resistance to weathering in industrial atmospheres is expected to be 2 to 20 times as long as zinc-coated wire. The coated wire may be drawn after

coating to any desired thickness without affecting coating adhesion, the manufacturers say.

RMD-4001, a Bakelite C-11 acrylonitrile-styrene copolymer thermoplastic molding material has freer flowing characteristics than former C-11 materials without loss of any outstanding physical or

chemical properties. It is high in clarity and offers wide color possibilities. It has excellent resistance to attack by fruit juices, beverages, oils, detergents and cleaning fluids. Tensile and flexural strengths are 11,700 and 15,700 psi respectively.

(Continued on Page 25)

APEX for cathodic protection

MAGNESIUM ANODES

Corrosion control for under-ground and under-water pipelines and other metal structures regardless of all other methods used.

Anode folders or technical consultation with our engineers available upon request.

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EASTERN DISTRIBUTOR:
Stuart Steel Protection Corp.,
2 Mark Road, Kenilworth, N. J.

SOUTHEASTERN DISTRIBUTOR:
Anti-Corrosion Mfg. Co.,
2464 Memorial Drive, S.E., Atlanta, Ga.

NEW PRODUCTS

(Continued From Page 24)

Graph-I-Tite, a carbon-filled graphite material that does not contain resins of any type has been developed by Graphite Specialties Corp., 64th St. and Pine Ave., Niagara Falls, N. Y. for use at temperatures up to 5700 degrees F. The material in preliminary testing has shown satisfactory performance when exposed to formic, hydrochloric, monochloroacetic and oxalic acids, ammonium hydroxide, ferric chloride, nidal sulfate, acetone, benzene, carbon tetrachloride, chloroform, ethylene dichloride, gasoline, isopropyl alcohol and trichlorethylene. Grade A features maximum impermeability and a high temperature limit of 1300 degrees F while Grade G for use at temperatures up to 5700 degrees F is slightly permeable to nitrogen at 40 psi but impermeable at this pressure to liquids with viscosities greater than water. Shapes and sizes up to two feet in diameter and nine feet in length are being made now with larger sizes planned for the future.

Model L-20 Penfield demineralizer will supply up to 20 gph of high purity water at a very low cost. The regenerative type demineralizer is said by manufacturers to produce 60 gallons of demineralized New York City water at a cost of 3 cents for chemicals. Manufacturer is Penfield Manufacturing Co., Inc., 19 High School Ave., Meriden, Conn.

Cross-Corrugated aluminum roll roofing and siding is being produced by Quaker State Metals Co., in 24 and 48-inch widths in rolls of 50,100 and 200 feet. Savings in handling are anticipated.

Ucon synthetic lubricants have been used in three power recovery engines in a large ammonia oxidation plant at temperatures ranging from 475 to 500 degrees F for more than a year without a shutdown. The lubricants are produced by Carbide and Carbon Chemicals Dept., Union Carbide and Carbon Corp., 30 East 42nd St., New York 17, N. Y. from whom technical information may be obtained.

A Performance Specification for Architectural Porcelain Enamel of Aluminum Alloys, a 4-page folder has been prepared by and is available from Ingram-Richardson Manufacturing Co., Beaver Falls, Pa.

SP-415, a hot surface aluminum paint recommended for application to surfaces subjected to heat up to 1000 degrees F may be applied by brush or spray. It dries in two hours on warm surfaces. The two-part coating is available from United Laboratories, Inc., 16801 Euclid Ave., Cleveland 12, Ohio.

Enamel Application by Dipping, a manual available from the Porcelain Enamel Institute, Inc., 1346 Connecticut Ave., N. W., Washington 6, D. C. considers four generally accepted methods of applying liquid porcelain enamel that come under the classification of dipping.

Seal Type Pumps made by Detroit Harvester Company, Pioneer Pump Division, Detroit, Mich. have a neoprene bellows-type seal and corrosion resistant design.

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a new color for
GACO N-700
Neoprene
Maintenance Coating
Available for the first time in
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N-700 Neoprene Maintenance Coating

GACO NEOPRENE PROTECTION PLUS—GACO N-700, Aluminum, gives all the performance-proven corrosion protection found in GACO N-700, Gray and Slate Black, *PLUS* the advantages of the aluminum color—light and heat reflection and beauty.

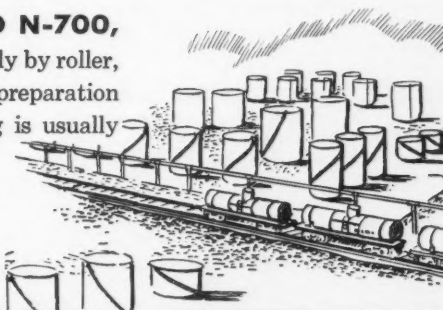
TIME TESTED—GACO N-700, Aluminum, has been field tested for over 100 weeks in severe corrosive fume conditions, and passed with flying colors. It retained its beauty, brilliance and corrosion protection qualities.

REFLECTS LIGHT & HEAT—GACO N-700, Aluminum, adds the light and heat reflecting qualities of aluminum to the long-lasting corrosion protection of genuine GACO Liquid Neoprene.

EASY TO APPLY—GACO N-700,

Aluminum, is easy to apply by roller, brush or spray. Surface preparation is simple—wire brushing is usually all that is necessary.

GACO N-700, ALUMINUM is not recommended for service in presence of acid halides because these agents cause it to discolor. GACO N-700 gray or black should be used instead.



Send me complete practical and technical data on this genuine Neoprene Maintenance Coating that goes on like paint at lower applied cost.

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PERSONALS

Lee H. Morrison of New York has been named editor of the magazine *Plating*, published by the American Electroplaters' Society.

Murray P. Ellis has been made South-eastern territory sales representative by the Protective Coatings Division of Pittsburgh Coke & Chemical Co.

Carboloy Department of General Electric Co., Detroit, has named **Edgar W. Engle** manager of cemented carbide products engineering.

William H. Shenkle has been made chief engineer of the Instrument Division of Rockwell Manufacturing Co. at Tulsa, Okla.

J. R. Connell has been appointed assistant general purchasing agent of the Boiler Division of the Babcock & Wilcox Co., Barberton, Ohio.

Fielden Instrument Division of Robertshaw-Fulton Controls Co. has added **Donald Daily** and **William H. Johnson** to the sales staff.

Robert J. Rickett was appointed physicist on the staff of Central Research Laboratories, Inc., Red Wing, Minn.

E. H. Stephens, former Wichita Branch

Manager of Westinghouse Electric Corp., has been transferred and is now branch manager in Tulsa, Okla. His new address is c/o Westinghouse Electric Corp., 600 S. Main, Tulsa, Okla.

Kenneth G. LeFevre and **Joseph H. Briscoe** have been appointed to the staff of Protective Coatings Div., of Metalweld, Inc., Philadelphia. They will serve in the New England, Eastern and Southern territory.

Fred C. Foy, vice-president and general manager of Tar Products Div., Koppers Co., Inc., has been elected a member of the Koppers board of directors.

Cardinal Chemical, Inc., Odessa, Texas, has made two additions to its sales force. They are **Jim C. Orchard** and **Frank Jones**.

St. Joseph Lead Co., 250 Park Ave., New York City, has appointed **William A. Ross** sales representative in the metal department.

Pratt Institute, Brooklyn has inaugurated **Dr. Francis H. Horn** as its new president.

Appointed director of engineering research and development for Whirlpool Corporation, St. Joseph, Mich., is **J. Paul Jones**.

O. E. McCullough, Jr. has been put in charge of cold coating sales at the Dallas office of Pittsburgh Coke and Chemical Company.

T. Ed Griffith has been named supervisor of Gas and Gasoline Plant Operations in the Central Division of the Tide Water Associated Oil Company at Tulsa.

Elmer R. Kaiser has joined the American Society of Heating and Ventilating Engineers as director of research. He has been engaged in research work, especially in fuels, at Battelle Memorial Institute for the past 20 years.

D. L. Edmunds has been named chief engineer of Mechanical Industries, Inc., Pittsburgh.

P. L. Coddington has been appointed general manager of Alloy Tube Division of the Carpenter Steel Company, Union N. J.

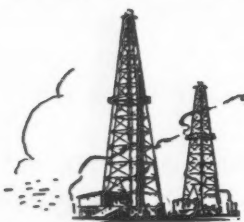
Norman B. Pilling, director of the Bayonne Research Laboratory of The International Nickel Co., Inc. since 1949 has been appointed assistant to the vice-president-manager of the company's Development and Research Division, New York. **W. Andrew Wesley**, assistant director of the Bayonne laboratory succeeds Mr. Pilling, with title of manager and **John T. Eash**, assistant director since 1939 becomes assistant manager.

Edgar E. Wrege has been named leader of the newly created experimental engineering section of the Research and Development Department of American Viscose Corp., Philadelphia.

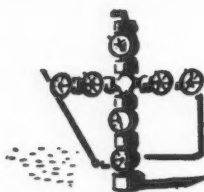
Ralph A. Schaefer, vice-president of the Clavite-Brush Development Co., a subsidiary of Cleveland Graphite Bronze Co., has been elected president of the American Electroplaters' Society.

TK-2 SOLVES PIPE CORROSION AND PARAFFIN PROBLEMS

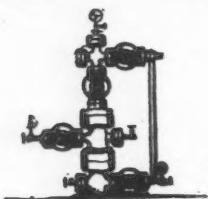
Here's why more than 7 million feet of pipe now in service are lined with TK-2 thermosetting plastic.



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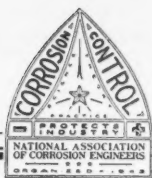
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Corrosion Abstracts

Index to CORROSION ABSTRACTS

Vol. 10 September, 1954 No. 9

	Page
1. GENERAL	
1.5 Directories of Material	217a
1.6 Books	217a
1.7 Organized Studies of Corrosion	217a
2. TESTING	
2.1 General	217a
2.2 On Location Tests	217a
2.3 Laboratory Methods and Tests	217a
2.4 Instrumentation	218a
3. CHARACTERISTIC CORROSION PHENOMENA	
3.2 Forms	218a
4. CORROSIVE ENVIRONMENTS	
4.2 Atmospheric	218a
4.6 Water and Steam	219a
4.7 Molten Metals	222a
5. PREVENTIVE MEASURES	
5.2 Cathodic Protection	228a
5.3 Metallic Coatings	230a
5.4 Non-Metallic Coatings and Paints	234a
5.5 Oil and Grease Coatings	240a
5.6 Packaging	240a
5.8 Inhibitors and Passivators	240a
5.9 Surface Treatment	241a
6. MATERIALS OF CONSTRUCTION	
6.2 Ferrous Metals and Alloys	242a
6.3 Non-ferrous Metals and Alloys—Heavy	244a
6.4 Non-ferrous Metals and Alloys—Light	244a
6.6 Non-Metallic Materials	250a
7. EQUIPMENT	
7.1 Engines, Bearings, and Turbines	252a

1. GENERAL

1.5 Directories of Material

1.5, 5.3.2, 4.2.1, 5.8.2
Coatings Cut Corrosion Costs. L. G. JONES. *Power Eng.*, 57; Nos. 7, 8; 87-89, 74-75 (1953) July, August.

Proper selection of corrosion resistant metals and metallic coatings is discussed. Tables give data on loss of metal for materials, such as copper, bronze, brass, copper-nickel alloy and nickel, exposed to different atmospheres for 10 years. Other tables give useful information on inhibitors which will prevent corrosion between various metals and their environment and effects of various corroding agents encountered in industry on industrial metals and alloys, such as steel, cast iron, nickel cast iron, nickel steels, stainless steels, nickel alloys, copper alloys, aluminum, tin and lead. Comparison is made of the life of hot-dip galvanizing and cadmium plating.—INCO 7088

1.6 Books

1.6, 3.2.3, 3.7.4, 3.2.4

Progress in Metal Physics. Vol. 4. B. CHALMERS. Book, 1953, 403 pp. Pergamon Press Ltd., London.

Contains monographs: A. S. Nowick, "Internal Friction in Metals"; K. Hauffe, "The Mechanism of Oxidation of Metals and Alloys at High Temperatures"; C. R. Cupp, "Gases in Metals"; G. A. Geach, "The Theory of Sintering"; A. H. Cottrell, "Theory of Dislocations"; A. Le Claire, "Diffusion in Metals"; J. H. Hollomon and D. Turnbull, "Nucleation." Detailed author and subject indexes are provided.—BNF. 6935

1.7 Organized Studies of Corrosion

1.7.3, 8.8.1, 5.4.5

Paint and Corrosion Committees Help Dow Chemical Fight Corrosion. *Plant*, 7, 47-49 (1953) May.

Discusses work of committees who test various materials; make regular surveys of the plant; set up manuals and specifications and act as clearing houses for the interchange of data on painting and corrosion. Photographs.—BTR. 7336

2. TESTING

2.1 General

2.1.1, 2.2.1, 2.2.2

Some Applications of Statistical Methods to Exposure Trials. I. Analysis of Exposure Data. H. R. TOUCHIN. *J. Oil Colour Chemists' Assoc.*, 36, 709-720 (1953) Dec.

Examples are given of statistical analysis of exposure data. Tables, graph. 23 references.—BTR. 7249

2.1.1, 2.4.3

Statistical Quality Control. The Introduction of a Form of Sampling Inspection. L. GRIFFITHS. *Automobile Engr.*, 43, 453-458 (1953) Nov.

Reviews elementary statistical theory, control charts, control limits, sampling intervals and applications to automatic production. Graphs, tables. 12 references.—MR. 7139

2.2 On Location Tests

2.2.2, 3.4.8, 6.3.19, 6.2.1

The Effect of Climate and Atmospheric Pollution on Corrosion (of Zinc and Ferrous Materials). J. C. HUDSON AND J. F. STANNERS. *J. Applied Chem.*, 3, Pt. 2, 86-96 (1953) Feb.

Read before a joint meeting of sections of the Society of Chemical Industry. Results of corrosion tests in which unprotected zinc and ferrous specimens are continuously exposed to different atmospheres throughout the world are presented and discussed. The degree of correlation between corrosion, both of the zinc and the ferrous samples and sulfur pollution of the atmosphere at British sites clearly demonstrates that the sulfur dioxide concentration in the air is the determining factor in the rate of corrosion of these metals in this country. The corrosion rate for zinc is proportional to the sulfur pollution, but

the rate for copper-bearing steel increases more slowly with increasing pollution, indicating that in certain enclosed situations where sulfur pollution is very high it may be more economical to increase the thickness of unpainted steel rather than protect it with zinc.—MA. 7177

2.3 Laboratory Methods and Tests

2.3.2

The General Motors Research Corrosion Test: A Cyclic Humidity Accelerated Corrosion Test for Sheet Steel. A. J. OPINSKY, R. F. THOMSON AND A. L. BOEGEHOUD. Paper before ASTM, 55th Ann. Mtg., New York, June 23-27, 1952. *ASTM Bull.*, No. 187, 47-51; disc. 51-53 (1953) Jan.

New type of precision corrosion test was developed to study the corrosion resistances of bare steel specimens for those applications where the protective rust of specimens exposed on racks outdoors is not fully realized. A slow humidity cycle, an elevated temperature and a superimposed dip of a weak electrolyte were so arranged that an almost nonprotective rust is developed after an initial period. There is evidence that this test rates several steels in about the same order as atmospheric exposure testing. The magnitude of corrosion

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losses of steels exposed to this test is three times that of the same steels exposed to a modified ASTM salt-spray test for the same length of time. Comparison with atmospheric exposure was made to Inco steels exposed at Kure Beach and Bayonne. Discussion by F. L. LaOue. Illustrations and references.—INCO. 6877

2.3.2, 4.2.4, 2.2.2, 5.4.5

Value of Artificial Weathering Tests on Anti-Corrosive Paints. *Deut. Farben-Z.*, 7, No. 9, 343-346 (1953).

Over 100 German anti-corrosive paints as well as 150 panels coated with paints based on linseed oil, linseed stand oil and linseed/tung stand oil varnishes were examined 1) in a four-week accelerated weathering test simulating industrial conditions and 2) after a three-year exposure at three different sites in a chemical works. The accelerated weathering test was probably excessively severe, since only 50% of its results were confirmed in practice. There was a noticeable trend for paints which were satisfactory in the accelerated weathering test to fail in practice and vice versa. The unreliability of accelerated weathering testing is attributed essentially to the fact that the mechanical properties of paint films vary considerably with time, as elaborated with experimental results, whereas the accelerated weathering test is made on relatively fresh films. Accelerated weathering tests are valuable for research purposes only when interpreted in conjunction with practical results.—R.P.I. 7198

2.3.4, 4.7, 3.5.9, 8.4.5

Corrosion Tests for Liquid Metals, Fused Salts at High Temperatures. D. C. VRELAND, E. E. HOFFMAN, AND W. D. MANLY. *Nucleonics*, 11, 36-39 (1953) Nov.

Describes static and dynamic tests used to determine reactions between possible heat-transfer and container materials for nuclear applications.—BTR. 7234

2.3.7, 5.3.4

Thickness of Electrodeposited Coatings by the Anodic Solution Method. C. F. WAITE. *Plating*, 40, No. 11, 1245-1248, 1253-1254 (1953) Nov.

The hydrochloric acid drop test used for determining the thickness of chromium on nickel gave erratic results when applied to chromium plated directly on copper. Successful results were obtained with the anodic solution method developed by H. F. Francis, using both experimental cell and the production instrument (termed the Kocour thickness tester).—BNF. 7251

2.4 Instrumentation

2.4.2, 3.2.3, 3.8.4, 3.6.2

Application of Electric Models to the Study of Diffusive Phenomena in Differential Aeration Corrosion. G. BIANCHI. *Metallurgia*, 45, 123-127 (1953).

Investigation on the possibility of the application of electric models to the study of diffusive phenomena, utilizing both direct field and conjugate field models. A brief review of the experimental methods used at present and a report of the results obtained with electric models in the study of oxygen diffusion in differential aeration corrosion. The com-

parison of the results thus obtained with the results obtained from corrosion tests on zinc, confirms the reliability of the method and of the assumption formulated by which the oxygen concentration is nil in the layer of solution that wets the metal.—MI. 6928

2.4.2, 5.4.5

The Protectometer and the Evaluation of Anti-Corrosive Primers. M. A. DANFORTH, K. H. E. LARSON, AND WOUTER BOSCH. *Paint, Oil Chem. Rev.*, 116, 48-52+ (1953) Nov. 5.

Describes an electrochemical device and its applications in predicting life of protective coatings. Diagrams, photographs, tables. 14 references.—BTR. 7116

2.4.3

Novel X-Ray Diffraction Technique for Measuring Internal Stresses in Metals. (In German). I. SZANTO. *Acta Tech. Acad. Sci. Hung.*, 7, No. 1-2, 165-186 (1953).

A new method of testing steel has been made attainable a degree of precision identical with current radiographic techniques, but by a much simpler measuring procedure. Tables, graphs, photographs, diagrams. 15 references.—BTR. 7208

2.4.3

Sound Waves Uncover Inner Flaws. *Steel*, 133, 120-121 (1953) Dec. 14.

Ultrasonic method of nondestructive testing particularly suited for inspection of heavy sections. Photographs.—MR. 7210

2.4.3

Measure for Effectiveness of Protective Coatings. (In French). A. WALTER. *Metaux: Corrosion-Industries*, 28, No. 329, 43-46 (1953) Jan.

Portable apparatus for determining dielectric strength of protective coatings. Testing in general. Photographs, diagrams.—MR. 7243

2.4.3

Testing Complexly Shaped Parts With Ultrasound. (In German). ERICH MARTIN AND KARL WERNER. *Arch. Eisenhüttenw.*, 24, No. 9/10, 411-422 (1953) Sept./Oct.

Numerous examples are presented to show that the oblique application of the impulse-echo process is especially suitable for detecting defects. Photographs, diagrams.—BTR. 7138

2.4.3

Industrial Evaluation of Search Coil Flaw Detection Techniques. C. H. HASTINGS AND G. A. DARCY. *Non-Destructive Testing*, 11, 24-29 (1953) May.

Clarifies basic techniques and presents additional experience in the use of a search coil technique for magnetic flaw detection. Photographs, diagrams.—BTR. 7156

2.4.3

Commercial Interpretation of Magnetic Particle Tests Correlated With Radiography and Physical Tests. A. F. COTA AND J. J. CHYLE. *Nondestructive Testing*, 11, 34-40 (1953) Jan.

Testing program includes inspection by means of radiographic, magnetic particle, penetrant, ultrasonic, hydrostatic, ionization, thermal and visual methods to anticipate permissible loading of the product. The tests and equipment used. Photographs and diagrams.—MR. 6838

2.4.3, 2.3.9

Betatron and Isotope Radiography. A. VON ARX. *Brown Boveri Rev.*, 40, No. 8, 289-295 (1953) Aug.

Describes the limits of application of radioisotopes, X-ray apparatus, and betatrons and their respective advantages and disadvantages. Radiographs, photographs, diagrams. 4 references.—BTR. 7278

2.4.3, 5.4.5, 7.2

Social Engineers Improve Pearson Holiday Detector. A. LETO AND S. K. GALLY. Southern Calif. Gas Co. Paper, Pacific Coast Gas Assoc. Meet., Los Angeles, Feb. 18-19, 1953. *Gas*, 29, No. 3, 61-62 (1953) March.

An improved transmitter and an improved 1.1 lb. compact receiver for use in detecting holidays in pipe is described. 7110

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.3, 3.4.9

Various Individual Phenomena Occurring in the Metal-Water Interface. F. TOTT. *Metalloberfläche*, (A), 7, No. 12, A184-A185 (1953) Dec. (In German).

A discussion, based on the literature, on the behavior of oxygen immediately at the metal surface and the pH-value at the metal-aqueous solution interface.—BNF. 7288

3.2.3, 3.8.2

Chemical Engineering Fundamentals. *Ind. and Eng. Chem.*, 45, 891-968 (1953) May.

Includes Rate Theory and Homogeneous Reactions, R. H. Wilhelm, Heterogeneous Catalysis, M. Boudart; Molecular Transport Properties of Fluids, E. F. Johnson; Diffusion and Oxidation of Solid Metals, C. E. Birchenall; Colloidal and Surface Phenomena, Geoffrey Broughton; Computers, Statistics, and Mathematics, Arthur Rose, Joan A. Schilk, and R. Curtis Johnson; Fluid Dynamics, Thomas Baron and A. K. Oppenheim; Heat Transfer, E. R. G. Eckert; Mass Transfer, Robert L. Pigford; and Thermodynamics, J. M. Smith.—BTR. 6983

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.3, 7.6.4, 2.4.3

Developments in the BCURA Dew-Point Meter for the Measurement of the Rate of Acid Build-Up on Cooled Surfaces Exposed to Flue Gases. P. F. CORBETT D. FLINT AND R. F. LITTLEJOHN. *J. Inst. Fuel*, 25, 246-52 (1952) Nov.

Preliminary experiments in which the dew-point characteristics (due to condensed sulfuric acid) of 18 different boiler installations were measured using the BCURA dew-point meter indicated that the rate of acid build-up is an important factor in assessing the potentially corrosive nature of flue gases. Using this, a new type of meter element was designed in which the electrodes are ar-

ranged annularly. The superiority of this over the parallel setting is demonstrated. 6673

4.2.5, 6.4.2, 3.6.6

Observations on the Behaviour of Light Alloys and Heterogeneous Assemblies in Marine Atmospheres. A. GUILHAUDIS. *Rev. Met.*, 49, No. 11, 791-799; disc., 799-800 (1952).

Guilhaudis describes the results of practical corrosion tests of light alloys in sea-air at various stations on the Mediterranean and Atlantic coasts of France. Corrosion appeared on the specimens during the first few months of exposure and they then became stable. Light alloys could be used without protection, but their tarnishing is unpleasant and they are better protected by anodic oxidation. However, local corrosion can occur in spite of this protection if aluminum alloys are in contact with other metals, in particular steel and such junctions should be protected by metal spraying with aluminum or zinc or by painting with zinc chromate.—MA. 6776

4.6 Water and Steam

4.6.2, 5.8.2

Film-Forming Amine for Corrosive Condensate. *Paper Trade J.*, 137, No. 1, 32 (1953) July 3.

Hagaofilm controls corrosion due to oxygen and acid carbon dioxide in steam condensate systems. The material, fed to the boiler in small amounts, vaporizes with the steam and deposits a very thin, non-wettable film on all metal surfaces wherever condensation occurs and throughout the return system. Advantages are diagramed. When added to feedwater it protects heat transfer surfaces and return piping against corrosion, reduces trap maintenance, keeps lines clear, improves valve and pump operation, minimizes transfer of iron to boiler and contributes to protection during standby periods. Material is supplied in solid and liquid form by Hagan Corp.—INCO. 6960

4.6.2, 5.8.2, 7.4.2

Corrosion in Condensate Return System. J. L. THORNLEY. *Bird-Archer Co. Industry & Power*, 65, No. 2, 58-60 (1953) August.

Action of dissolved gases, including oxygen, carbon dioxide and possibly sulfur dioxide and hydrogen sulfide, is the chief cause of corrosion in condensate return systems. Effective agents for reducing or preventing corrosion are ammonia, ammonium compounds and amines. Theory of corrosion, influencing factors, effect of impurities, methods of feeding treatments and relative characteristics of the preventive agents are discussed. Illustrations, graphs.—INCO. 7332

4.6.2, 5.8.2, 5.7.7

Amines for Corrosion Prevention in Steam Condensate Systems. C. JACKLIN. *National Aluminate Corp. Corrosion (News Section)*, 9, No. 7, 1 (1953) July.

Although the amount of corrosive carbon dioxide in high-pressure steam condensate systems is usually kept low by water preconditioning, even a near neutral pH presents a serious corrosion problem where large amounts of condensate are circulated. Amine-type chemicals have been used to control corrosion in steam condensate systems for several years, but only recently has their use been extended to the successful and eco-

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4.6.4, 7.1, 5.8.2

Cooling System Corrosion Problems. R. S. WISE. *Diesel Power*, 31, 64-66 (1953) Dec.

Use of corrosion inhibitors in water-

cooled Diesel engines. Photographs, diagram.—MR. 7202

4.6.6, 4.3.2, 3.4.10

Modification in Corrosion Effects Through the Use of Wetting Agent; Pt. IV. Its Protective Effect Against Acid Action. (In German). L. PIATTI. *Werkstoffe u. Korrosion*, 4, No. 5, 153-156 (1953) May.

Earlier investigations have shown that the addition of a suitable wetting agent to domestic water supplies would not only prevent pitting, but would counteract practically any form of corrosive action. The action of dilute hydrochloric acid on steel can be appreciably reduced by the addition of a suitable wetting agent as shown by tests. Even 0.4 percent in a solution of 22 g. hydrogen chloride is 1000 ccm water has a strong

inhibitory effect, while the presence of 1 percent guarantees protection of the steel.—INCO. 6837

4.6.6, 8.1.4, 5.7.3

Rust in Water System Checked by Deaeration. J. L. STAUNTON. Seeley, Stevenson, Value & Knecht. *Eng. News Record*, 151, No. 9, 42-43 (1953) Aug. 27.

At U. S. Naval Hospital at St. Albans, L. I., a vacuum deaeration system was installed to prevent corrosion of the water system which is a function of the dissolved oxygen in the water. The water which is supplied from a deep well system is very corrosive to the hospital's steel piping. Dept. of Navy is devising a system of checks to maintain a record of the effectiveness of the installation. Illustration.—INCO. 7187

4.6.11, 7.4.1

Protection of Heat Exchanger Channels and Covers from Corrosion by Salt Water. W. J. DANZIGER AND O. A. SUNDHOLM. M. W. Kellogg Co. Paper before ASME, Ann. Mtg., Nov. 30-Dec. 5, 1952, N. Y. Am. Soc. Mech. Engrs. Preprint, Paper No. 52-A-145, 1953, 17 pp.

Methods and materials which were used to protect heat exchanger channels, channel covers and floating head covers from salt water corrosion are discussed and experience with some of these materials is reported. Materials used are 18-8 molybdenum, 20 chromium, 12 chromium, HE Meehanite, Ni-Resist No. 1 and 2, 8 chromium-molybdenum, carbon steel, nickel-molybdenum iron, 6 chromium-molybdenum and 5 nickel steel. Methods are cathodic protection of ferrous materials, coatings on ferrous materials, linings on ferrous materials and the use of nonferrous resistant materials. Diagrams and references.—INCO. 7053

4.6.11, 8.1.4

Scale Formation in Sea-Water Distilling Plants. H. HILLIER. *Inst. Mech. Engrs.*, Advance Copy, Jan., 1953, 19 pp. *Engineer*, 195; 208-209, 255-256 (1953) Feb. 6, Feb. 13; *Engineering*, 175, 378-380, 442-444 (1953) Mar. 20, Apr. 3.

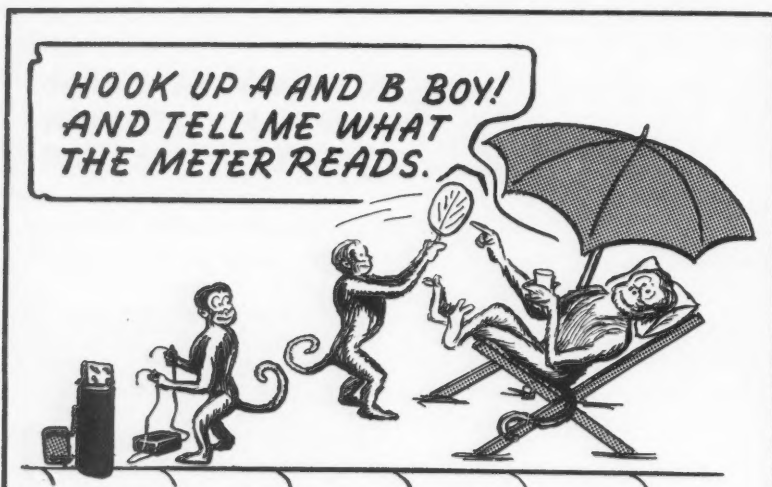
Discusses typical performance of an evaporating plant and a test plant with testing procedures and results. Part 2 discusses treatment of calcium carbonate scale with hydrochloric acid, sulfuric acid, sodium acid sulfate, ferric chloride, organic dispersives and phosphate compounds. Graphs.—BTR. 7168

4.6.6, 5.7.1, 3.3.4

Red Water and Its Prevention. PHILIP S. DAVY. *J. Am. Water Works Assoc.*, 45, No. 1, 10-18 (1953) January.

Red water is basically caused by one or more of the following factors and frequently by all three: 1) the presence of iron or manganese or both in the raw water; 2) a corrosive water supply; and 3) the growth of iron bacteria in the distribution system. Unless all three are taken into consideration, treatment is usually only partially successful.

When the raw water supply contains iron or manganese in excessive quantities (more than 0.3 ppm combined iron and manganese) the problem of red water occurs throughout the system, although it may be worse in dead ends or areas of little circulation. The principal basic methods of removal include aeration followed by coagulation and filtration, pressure aeration and filtration



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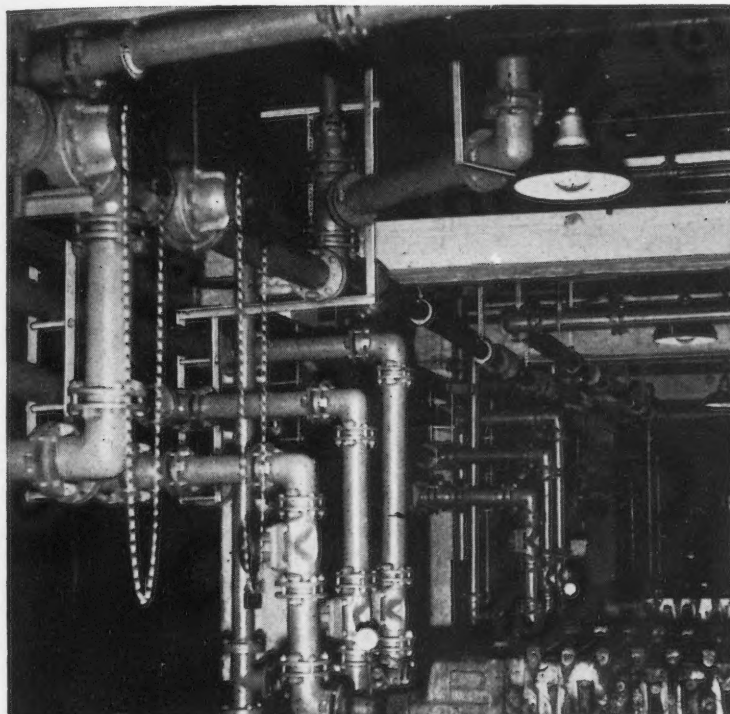
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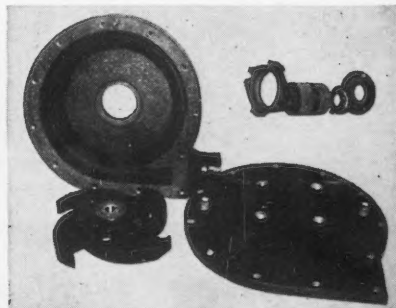
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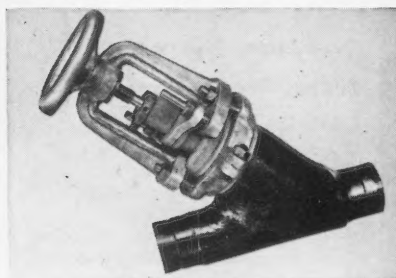
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and cation exchange. Cation exchange usually results in soft water with a combined iron and manganese content of less than 0.2 ppm.

Ground water is frequently corrosive even when only traces of iron and manganese are present. It is almost invariably corrosive when appreciable amounts exist because these minerals are introduced largely by corrosive water. In Wisconsin the principal source of corrosion is free carbon dioxide. Adjustment of the pH to 8.2-8.4 with lime or sodium hydroxide usually results in elimination of iron pickup in the distribution system. Proprietary compounds containing phosphates also eliminate red water caused by corrosion. These compounds act by building up a protective film on the metal surface. Because of low velocities

in the dead ends, these areas may not be sufficiently protected. Because phosphates are a good source for iron bacteria, a low rate of chlorination is a desirable adjunct to phosphate stabilization.

Red water complaints usually arise in areas of little circulation and bacteriological smears in these regions usually indicate the presence of sulfate-reducing or iron-consuming bacteria. The *Desulfuricans* bacteria reduce the sulfates in the water to hydrogen sulfide which attacks the pipe, dissolving the iron and placing it in solution in the water. The iron-consuming bacteria, such as *Crenothrix*, *Leptothrix*, and *Coccobacillus*, seem to require iron already in solution and do not utilize iron from the pipe as a food source. Pitting of iron pipe occurs, however, when these bacteria are present in

quantity. Control agents are chloramine or continuous or massive doses of chlorine. If iron pickup due to corrosion is controlled, a period of 1 yr. or more can elapse before iron bacteria create a red water problem. A massive chlorine dose over a 24-hr. period, and a thorough flushing of the system will restore the water to a satisfactory condition.—PDA, 6996

4.6.11, 6.4.2, 8.9.5, 5.4.5

Anti-Fouling Paints for Aluminum Alloys Used in Shipbuilding. J. C. KING-COME. *Paint Manuf.*, 23, No. 1, 5-10, 29 (1953) Jan.; *Light Metals*, 16, No. 179, 48-52 (1953) Feb.

The latest U. S. Navy practice and recent Admiralty trials suggest that anti-fouling paints containing copper compounds can be safely used on aluminum hulls, provided a good corrosion-inhibiting primer is first applied. The U. S. authorities specify an etch primer, containing zinc tetroxochromate, followed by other coats of zinc chromate primer and finally an anti-fouling paint pigmented with cuprous oxide. All the paints are based on polyvinyl resins. The British tests showed that Admar protective paint could be used successfully over the zinc chromate etch primer; the lead compounds in the protective paint seemed to have little tendency to promote corrosion at breaks in the coating. A resin-based cuprous oxide anti-fouling paint was used.—ZDA, 6308

4.7 Molten Metals

4.7, 2.4.2, 2.3.4

Investigation of Materials for Use in a Heat Transfer System Containing Liquid Lead or Bismuth. O. CUTLER SHEPARD, JAMES R. MORGAN, RALPH PARKMAN, KENNETH L. KEATING AND RICHARD D. SEIBEL. Stanford Univ. School of Mineral Sciences, April 1, 1953, 25 pp.

Results are reported of capsule tests of the rates of solution and solubility limit of steel in molten bismuth, tests of the effects and preoxidation of surfaces on solution, tests of the wetting of solid metals by liquid metals and determinations of the activity coefficients of zinc in liquid bismuth. Drawings of a capsule solution test unit used to determine rates of solution and solubility limit of steel in molten bismuth, a liquid-metal heat-transfer system using cell potentials to continuously monitor dissolved metal concentration in a liquid-metal system, a cell for measuring the chemical activity of nickel in liquid bismuth and a still for refining liquid bismuth samples, are included. The effects of oxygen on corrosion and the relation of wetting of solid metal by liquid metal to oxidation and corrosion are discussed. Analytical procedures for determining trace amounts of iron and chromium in bismuth are reviewed and a block diagram of procedures is included. The substitution of spectrographic methods for colorimetric methods for bismuth analysis is discussed.—NSA, 6911

4.7, 6.3.10

The Thermal Properties of Sodium Hydroxide and Lithium Metal; Fourth Progress Report: November 1, 1952-January 31, 1953. R. R. MILLER. Naval Research Lab., March, 1953, 7 pp. (NRL-Memo-130; Progress Report No. 4).

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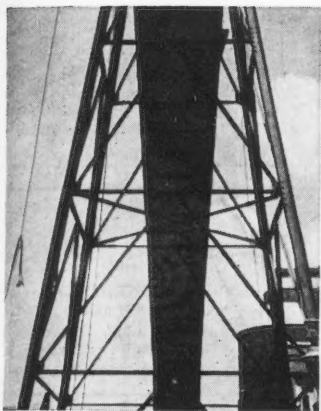
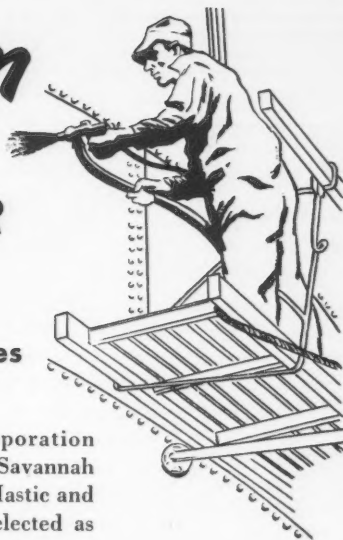
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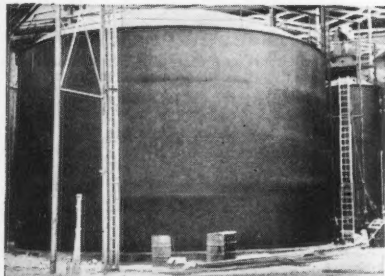
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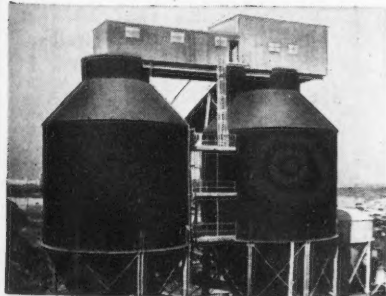


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ceptibility measurements have thrown new light on the mechanism of the sodium hydroxide-nickel reaction. The mechanism involves a reaction which lends itself to semi-reversal, and to nearly complete inhibition by the employment of a hydrogen atmosphere and controlled temperature gradients. Equilibrium pressures for the reaction are given for the 700 to 1100 degrees C range. Conditions required for inhibition of mass transfer and reaction include a pressure of pure hydrogen in excess of the equilibrium pressure of the reaction and elimination of excessive free or dead space in the system. A static system is preferable, also. Nickel of high purity has been selected as a container material for physical property measurements on sodium hydroxide. (No work on lithium is reported.) —NSA. 6846

4.7, 6.3.10

Inconel Pots for Alkali Fusions. R. S. YOUNG, D. A. BENFIELD AND K. G. A. STRACHAN. *Metallurgia*, 48, No. 290, 318 (1953) Dec.

Alkali fusion for recovery of diamond powder from industrial wastes is usually carried out in cast iron or stainless steel pots, both having a high corrosion rate. Welded pots of Inconel, 3/32 in. thick, were tested. Rate of corrosion was measured by quantity of nickel in nickel-free potassium hydroxide or sodium hydroxide and rates of 189 and 193 mg./dm.²/24 hr. respectively were found, attack being uniform without pitting.—BNF. 7228

4.7, 7.3

Mechanical Pumps for High-Temperature Liquid Metal. P. M. CLARK. Knolls Atomic Power Lab. Paper before ASME,

Ann. Mtg., N. Y., Nov. 30-Dec. 5, 1952. *Mech. Eng.*, 75, No. 8, 615-618 (1953) Aug.

Type 347 stainless steel and pure nickel are sufficiently resistant to corrosion for use in pump parts in contact with liquid metals such as sodium and sodium-potassium. Pump shaft, drain tank, floor plate and most of the part within the drain tank are of Type 347 stainless. Shaft-cooler bushing and the gaskets are made of nickel. Shaft has a Steelite facing opposite the shaft-cooler bushing and all bolts have a hard nickel plate or nitrided surface to prevent galling.—INCO. 7004

4.7, 1.6, 6.5

Final Report on Metallurgical Investigation of Materials Subjected to Liquid Lead-Bismuth Alloy Environment. R. C. GRASSI, D. W. BAINBRIDGE, AND J. W. HARMAN. U. S. Atomic Energy Commission Publ. (AECU-2201), 72 pp., 1952.

Stress-rupture data were obtained for molybdenum at 1600 degree and 1800 degree F (870 degree and 980 degree C.) and for niobium at 1800 degree F in helium, lead and bismuth. An anomalous increase in effective strength was found for molybdenum at both 1600 degree and 1800 degree F in lead and bismuth; at 1800 degree F the load for fracture in 100 hours was 13 percent greater in bismuth than in helium and 7 percent greater in lead. No significant surface attack by the liquid metals was noted. The strength of niobium was slightly less in lead than in helium for tests of <100 hours. Lead caused no major solution attack, but micrographic studies showed the presence of a new surface phase with a slight penetration. Bismuth caused the development of surface fissures in niobium and the attack was accompanied by a marked loss in strength and ductility. When niobium was welded to molybdenum, large grains were developed, together with the formation of an unknown precipitate in the grain boundaries which resulted in marked weakening of the material in liquid bismuth at 1800 degree F. In static solution tests in lead and lead-bismuth, iron, chromium, nickel and manganese were found to dissolve in appreciable amounts from a low-alloy steel, an austenitic stainless steel and various ferritic stainless steels in the temperature range 1400-2000 degree F (760-1095 degree C). The liquid became rapidly saturated with iron, which was displaced from solution with further solution of chromium; this effect was more pronounced in lead than in lead-bismuth alloy. Nickel also appeared to have a precipitating influence with respect to iron and chromium. For all the materials studied, the eutectic lead-bismuth alloy was more reactive than lead and dissolved ~5 times the amount of all steels tested. Metallographic evidence suggested that surface decarburization occurred for some steels and the degree of general attack increased with the concentration of chromium and nickel in the steel. No evidence of attack was obtained for molybdenum in lead at 1400-2000 degree F and it appeared that niobium was unattacked by lead. A review is given of the complete results to date and suggestions are made for further work.—MA. 6816

4.7, 2.3.9, 6.2.2

The Solubility of Iron in Sodium Metal, Sodium-Sodium Oxide and Sodium-Sodium Oxide-Sodium Hydroxide.

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What to do about corrosion when you process hot chlorine or hydrogen chloride at 500° to 1000° F.

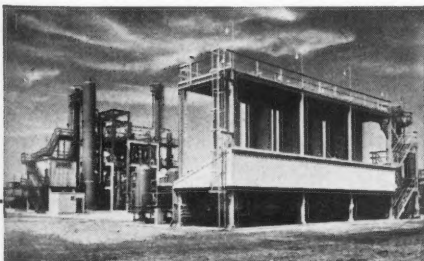
Here's what research by a large chemical company has revealed about corrosion of alloys in dry chlorine and hydrogen chloride as temperatures go up.

The corrosion rate rises but slowly... up to a certain critical point. Then gallops.

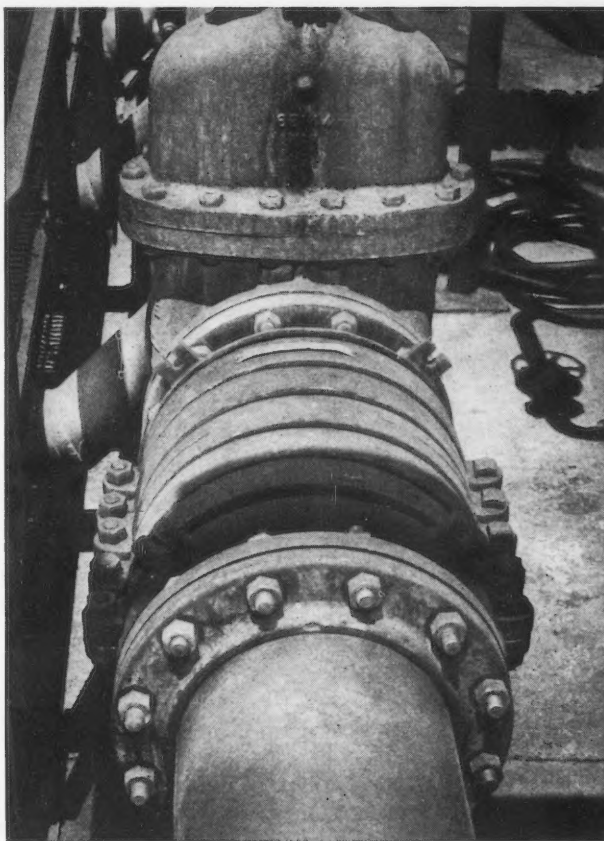
The point where severe corrosion begins varies with the alloy . . . depends largely on the temperature at which protective metal chlorides break down.

Iron, steel, and aluminum, for example, were all found to ignite below 500°F. in dry chlorine. Copper around 600°F. Not so with Nickel and Inconel. They were found useful up to about 1000°F. in dry chlorine. The *most* useful of all alloys tested, in fact.

In dry hydrogen chloride, Nickel does well up to 950°F. . . . Inconel up to 900°F.



Hydrogen is burned with chlorine in these towers to produce hydrogen chloride. Nickel sleeves protect reactant feed lines. In the same plant, Nickel domes collect chlorine over electrolytic cells at temperatures in excess of 1000°F.



Hot chlorine and hydrogen chloride line in a carbon tetrachloride plant, showing an Inconel expansion joint and Inconel flange bolts. Elsewhere, this plant uses 3" Inconel furnace pipes to heat process gases for chlorinating hydrocarbons.

Experience in many installations bears out that Nickel, Inconel and other high nickel alloys protect equipment and product against the action of these gases at high temperatures. Two installations are illustrated.

So if you have a hot chlorine or hydrogen chloride corrosion problem . . . make sure you have the facts. Write for free copies of "Corrosion by Chlorine and by Hydrogen Chloride at High Temperatures" and Inco's Technical Bulletin T-29. And be sure to contact Inco's Corrosion Engineering Section.

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ANDREW D. BOGARD. Naval Research Lab., Mar. 9, 1953, 10 pp.

The solubility of iron in sodium metal has been determined across the temperature range 236-540 degree C in a static system using 46.3-day Fe^{59} as a tracer. The solubility of iron in sodium metal follows the expression: $\text{wt. \% Fe} = 2.88 \times 10^{-4} - 1.63 \times 10^{-6}T + 5.63 \times 10^{-12}T^2$, where T is the temperature in degrees-centigrade. Sodium monoxide, across a similar temperature range increases the solubility of iron in sodium metal by a factor of approximately 10. The solubility at any temperature between 200 and 560 degree C may be calculated from: $\text{wt. \% Fe} = 3.17 \times 10^{-6} - 1.71 \times 10^{-8}T + 3.51 \times 10^{-12}T^2$. The combined effect of sodium monoxide and sodium hydroxide increases the solubility by another factor of approximately 10 across the temperature range 250-560 degree C. The curve follows the expression: $\text{wt. \% Fe} = 8.23 \times 10^{-4}T - 1.30 \times 10^{-6}$. It was found that impurities in the iron undetectable by chemical or spectroscopic methods appeared in the sodium metal. A stainless-steel and nickel apparatus was used, in which a sample of sodium was distilled onto the radioactive iron and the sample was removed after saturation at a given temperature and stored in a sample receiver until a series of determinations had been completed. The iron dissolved in the sodium was determined radio-metrically.—NSA. 6795

4.7, 2.4.2, 6.2.5

Stress-Rupture and Corrosion Tests of Type 347 Stainless Steel in Molten Eutectic Lead-Bismuth Alloy. First Annual Report for the Period June 1, 1951 to May 31, 1952. FRANCIS H. LAXAR. Le-

high Univ., 10 pp. (NP-4439), May 31, 1952.

The determination of stress-rupture and corrosion properties of stainless steel when immersed in molten bismuth-lead alloy at temperatures of 800, 900 and 1000 degree F is presented together with a description of equipment and testing procedures.—NSA. 6751

4.7, 3.5.9, 6.6.6

The Corrosion of Refractory Materials in Sodium. R. L. LOFTNESS, W. C. RUEBSAMEN, AND T. A. COULTAS. North American Aviation, Inc. (AECD-3472; NAA-SR-126). Issued Nov. 20, 1951. Decl. with deletions Dec. 1, 1952, 41 pp.

The corrosion of refractory materials in liquid sodium and sodium vapor at 900 degrees C for periods of time up to one month was studied under static conditions. Vacuum-distilled sodium was used in all but a few instances. Changes in weight, appearance and metallographic structure were observed and post-run chemical analyses of the sodium were made. In general the rates of corrosion were higher in liquid sodium than in sodium vapor. The presence of excessive oxygen in the sodium increased the corrosion rates. In order of decreasing resistance to corrosion by sodium at 900 degrees C the materials are: molybdenum, tungsten, Haynes Stellite-25 (cobalt, chromium, tungsten, nickel alloy). Type 347 stainless steel, Kennametal-138A (titanium carbide + cobalt), tantalum and titanium. Graphite, copper, platinum, spinel, alumina, magnesia and zirconia showed poor resistance. Silicon carbide, molybdenum silicide and thorium showed good resistance to corrosion. Synthetic sapphire and single crystal magnesia had good resistance. Experimental procedures and equipment are described. Analytical methods for presence of the following substances in sodium are described: oxygen, potassium, calcium, magnesium, silicon, aluminum, nickel, niobium, chromium, iron, molybdenum, tantalum, titanium, tungsten, zirconium, carbon and sodium carbide (evidenced by acetylene formation).—NSA. 6819

4.7, 6.2.2

Reactions of Solid Iron With Molten Aluminum and Aluminum Alloys. (In German). ERICH GEBHARDT AND WALTER OBROWSKI. *Z. Metallkunde*, 44, 154-160 (1953) Apr.

Examines growth layers of solid iron with molten aluminum and several aluminum alloys. This is done by measuring thicknesses of layers; studying their microstructures; testing hardness; and X-ray and chemical analyses. Tables, graphs, photomicrographs. 20 references.—BTR. 6339

4.7, 6.2.3

Permeability of Steel to Lithium. (In French). ALBERT HEROLD, PIERRE MULLER, AND PIERRE ALBRECHT. *Compt. rend.*, 235, 658-659 (1952) Sept. 29.

Commercial soft steel (0.1 percent carbon) tubes containing lithium were heated at various temperatures up to 1100 degrees C. Permeability was observed even at temperatures below 700 degrees C by spectrographic analysis of the exterior of the tube. Tubes previously annealed in hydrogen at 900 degrees C for a number of hours showed no permeability even at 1100 degrees C, although the same tubes subsequently heated at 600 degrees C in the presence of graphite permitted massive passage of lithium.

It is concluded that lithium traverses steel through fissures formed by dissolution of carbon. However, steel quenched from 1100 degrees C in cold mercury in order to retain the solid solution of carbon in γFe did not exhibit permeability even at 900 degrees C, fissure formation probably being rendered difficult by the presence of resistant masses of crystallized cementite.—NSA. 6719

4.7, 6.2.3, 6.2.4, 6.2.5

Formation of Stress Cracks in Steel by Molten Zinc. W. RADEKER. *Stahl und Eisen*, 73, No. 10, 654-658 (1953) May 7.

Investigation on formation of inter-crystalline cracks in steels (compositions given) as a result of action of liquid zinc. Damage was noted on bending under tension. Liquid zinc may have rapid destructive effect on grain boundaries. On prolonged tensile drawing fracture was observed well below ultimate tensile limit. The lower the stress the longer the time to rupture. At constant temperature time to rupture is related to tensile strength linearly when plotted on log-log paper. Elevated temperature decreases time to rupture. At equal tension steels with high heat resistance have longest time to rupture.—INCO. 6652

4.7, 6.3.9

Molybdenum Corrosion by Sodium. R. CYGAN AND E. REED. North American Aviation, Inc. U. S. Atomic Energy Commission Publ., AECD-3473, Issued Nov. 20, 1951. Decl. with deletions Dec. 1, 1952, 15 pp.

Investigations of corrosion with both liquid sodium and sodium vapor, carried out at low temperatures, have shown molybdenum to be one of the most promising of the refractory metals. This report gives the results of the first corrosion test on molybdenum in sodium vapor at 1500 degrees C that has been successfully completed. In addition to the usual grain growth, the molybdenum showed some intergranular-type attack with a maximum penetration of less than 1 mil.—NSA. 6764

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 7.7, 8.9.3

Grounding and Corrosion Protection on Underground Electric Power Cable Sheath and Oil- or Gas-Filled Pipe Lines. R. J. KUHN. Paper before AIEE, Fall Gen. Mtg., New Orleans, Oct. 13-17, 1952. *Trans. Am. Inst. Elec. Engrs.*, 71, Pt. III (Power Apparatus and Systems), 990-993 (1952) Dec.

Solution to the problem of obtaining satisfactory grounding and corrosion protection on underground electric cable sheaths and pipe lines is to provide a joint or common cathodic protection system with numerous bonds between the cable sheaths or pipe lines and other well-grounded structures. Another solution is individual cathodic protection. A satisfactory solution for new electric cable or pipe line installations involves the use of high resistance protective coating, insulation from external grounds at generating stations, provision of heavy-duty cross bonds, provision of special generating device to provide adequate cathodic protection, provision of

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special grounding devices and provision of special detecting devices. 4 references.—INCO. 6812

5.2.1, 8.9.3

Pipe Line Corrosion and Cathodic Protection. M. E. PARKER. *World Oil*; 136; Nos. 2, 4, 5, 6; 210-212, 222J-222L, 248F-248G, 270H-270I (1953) Feb. 1, March, April, May.

Direct and indirect methods of measuring soil resistivity are described. Surveys for hot spots and ground beds are covered. Voltmeters, slide-wire potentiometers, potentiometer-voltmeters and vacuum-tube voltmeters, measuring pipe to soil potentials are used in investigating corrosive conditions or in evaluating the extent of cathodic protection being applied. Line current measurements are described.—INCO. 7147

5.2.2, 8.9.3

Controlling Corrosion. A Manual on Underground Corrosion, Columbia Gas System Service Corp. *Oil Gas J.*, 52, No. 15, 155 (1953) Aug. 17.

Method for controlling corrosion along a pipe line by forcing current furnished by galvanic anodes to flow onto the pipe, either through its entire length or through selected portions. If all the area along a pipe line which is subject to corrosion can be made the cathode of a strong galvanic cell by using an expendable dissimilar metal, such as aluminum, zinc, or magnesium, as anode, the natural areas along the pipe can be suppressed and pit holes do not develop. Magnesium forms the strongest cell and is most often used. Illustrations.—INCO. 7102

5.2.2

Magnesium Anode Program. J. N. HUNTER, JR. Service Pipe Line Co. *Oil Gas J.*, 51, No. 23, 284, 287-288 (1952) Oct. 13.

Planning a practical magnesium anode program. Successful anodes are designed on the basis of graphs reflecting the results of past experience. The number of anodes required and average life of each anode can be determined by soil resistivity measurements and reference to graphs. A punched-card record can be used to show the location of each anode and when it should be replaced. Report form and graphs are given.—INCO. 6788

5.2.2, 8.9.5, 4.6.11

Magnesium Anodes. *The Log*, 47, 56-57 (1952) April.

Magnesium anodes to protect underwater ship surfaces from the ravages of sea water corrosion are now available to shipowners and operators after several years of successful testing. Corrosion of the underwater surfaces of ships is due primarily to some areas of the steel surfaces being more active chemically than other areas. When such conditions occur under water, small electric currents flow from the more active areas through the water to the less active areas. These currents, as they leave the active areas, remove particles of steel and, over a period of time, cause severe pitting of the ship's surface, resulting in serious and costly damage. Such corrosive action, it is claimed, can be controlled by simply stopping the flow of current away from the active areas of the ship's surface by the use of magnesium anodes. This method is known as cathodic protection. Magnesium is the

most active of the commonly used metals. When it is connected to steel the electrical current flows from the magnesium to the steel. If a sufficient quantity of magnesium is used, it prevents any current from leaving the steel, thereby controlling corrosion. Claims of the effectiveness of magnesium anodes have been substantiated by the Royal Canadian Navy which, following successful tests over the last three years on several small vessels, recently ordered this method of cathodic protection installed on several of its larger vessels up to and including aircraft carriers. Recently the Dow Chemical Company's 13,000 deadweight ton tanker Marine Chemist became the first large commercial vessel in active service in the United States to use magnesium anodes for protection against sea water corrosion. Some 7000 pounds of magnesium anodes were attached to the port and starboard sides of the Marine Chemist, several feet below the water line, directly aft of the bilge keel, for a length of about 75 feet on each side. The anodes, each with a length of 16 inches and weighing about 60 lbs., were designed to last a year, following which new ones will be installed when the tanker is dry docked for annual overhaul next October. The anodes are held securely in place by Monel metal six inch studs, one inch in diameter, "position welded" on the shell plate of the hull.—TIME. 6685

5.3 Metallic Coatings

5.3.2

Behaviour of Paints on Galvanized Steel. *Can. Paint & Varnish Mag.*, 26, No. 3, 33-36 (1952) March.

A discussion on the value of zinc coatings for protecting steelwork against corrosion under different atmospheric conditions. Under certain conditions it is necessary to provide additional protection by painting the zinc coating. Paint does not adhere to zinc applied by hot dip galvanizing. It is suggested that loss of adhesion arises from a) presence of zinc and iron chloride deposits where the surface has not been adequately washed, b) inherent smoothness of the zinc surface, c) reaction between zinc and acidic products of oil oxidation, e.g. formic acid, yielding a zinc salt interfacial layer of poor adhesion. Various methods have been devised for overcoming adhesion difficulty. One method is to allow the zinc to weather for a year or two, another is to apply a wash. Not all washes are said to be equally successful and the article gives no guidance on this point.—ZDA. 6762

5.3.2, 2.2.5

Full-Bath Zincification as Underwater Rust Protection. (In German). R. GLOOR. *Bull. assoc. suisse elec.*, 43, 984-986 (1952) November.

Full-Bath zincification has been applied successfully in Switzerland to protect various structures exposed to weathering. On many of these, the zinc coating is still intact after 30 years. This method also successfully protects iron in concrete in the soil, as well as iron buried directly in the soil. Full-bath zinc-coated iron in concrete was repeatedly shown to be more resistant than unprotected black iron. Underwater exposures have given contradictory results, mostly because of variations in the thickness of the applied zinc coating. Previous long-

term service tests (7 years) indicated that an average of 32 g. per sq. m. per yr. of zinc is lost from most underwater structures in Swiss rivers. Thus, a coating of 1000 g. per sq. m. should give 30-year protection. Under severe conditions, the annual zinc loss may be greater than 32 g. per sq. m., resulting in premature failure.—PDA. 6737

5.3.2, 5.3.4, 6.2.1

Aluminium and Zinc for the Protection of Iron and Steel. *Electroplating and Metal Spraying*, 6, No. 2, 75-79 (1953) Feb.

A summary of notes issued by the American Welding Society on the best current American practice in spraying aluminum and zinc for the protection of iron and steel. Only the wire process is referred to. The notes deal with surface preparation, the use of a sprayed steel bonding coat where very thick protective coatings are needed and the quality of the protective coating itself. Guidance is given on the thickness of metal to use under various conditions. Finally there are comments by English experts.—ZDA. 6304

5.3.2

A Corrosion Study of Various Chromium Plated Electrodeposits. H. BROWN AND E. W. HOOVER. Udylite Corp. Paper before Am. Electroplaters' Soc., 40th Ann. Conv., June 15, 1953. *Plating*, 40, No. 8, 874-878+ (1953) Aug.

Corrosion results in salt-spray, humidity and outdoor exposure tests are presented for various coatings, such as nickel, nickel-cobalt, nickel-iron, copper, chromium, gold and rhodium, which are cathodic to steel. Role of inherent porosity and electrochemically induced porosity is discussed for the various deposits in various combinations in the different environments. An interesting finding is detailed on the use of a thin rhodium plate between nickel plate and the final thin chromium plate that resulted in excellent protection of steel and other metals when exposed to an industrial atmosphere. Another finding is that of 0.2-0.6 mil thick bright nickel-iron alloy plate with a final thin chromium plate which protected brass in salt-spray and outdoor exposure tests equally as well as nickel plate of the same thickness and with the same final thin chromium deposit. This did not hold true for thicker nickel-iron deposits with subsequent chromium plate on steel. Illustrations and 12 references.—INCO. 7003

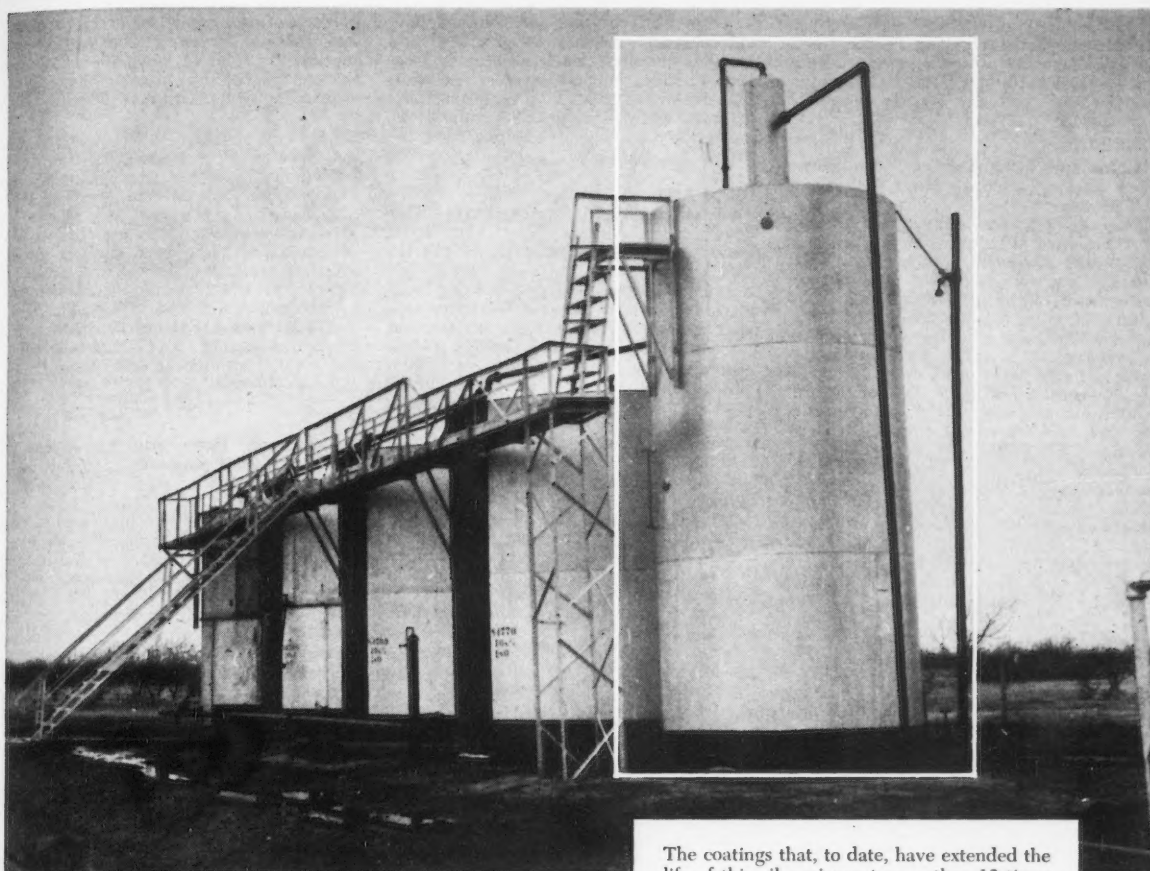
5.3.2

Notes on the Peeling of Nickel Deposits. EDMUND T. RICHARDS. *Metal Finishing*, 51; 64-67, 60-65 (1953) April, May. Points out most important causes. Ways and means to avoid and counteract them. 53 references.—MR. 7204

5.3.2, 6.2.3, 3.5.9

Coating Steel by the Aldip Process. D. K. HANICK AND A. L. BOEGEHOLD. Gen. Motors Res. Labs. Paper before SAE. Ann. Mtg., Detroit, Jan., 1953. *SAE J.*, 61, 40-45; disc., 46 (1953) April.

Aldip process for aluminum coating steel assemblies was developed for parts requiring high temperature oxidation resistance up to 1600 degrees F. Coated heat exchangers performed satisfactorily, resisting corrosion at the exit tank ends where exhaust gas condensate collects. Replacing Type 321 in this assembly produced a saving in strategic chromium and nickel. Fabricated SAE 1010 mani-



The coatings that, to date, have extended the life of this oil equipment more than 12 times were applied by **Mid-Continent Plastic Co.**, Odessa, Texas.

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This battery of Texas oil tanks shows a large 4-in.-steel gunbarrel tank in the foreground. It is used to separate salt water from crude oil. Both the salt and the hydrogen sulphide in the oil are highly corrosive. This gunbarrel tank was installed brand new. Within 30 days a hole appeared in its side. This was patched, and noticeable thin spots reinforced. Only 30 days more and leaking began again. Thus, after two months, two alternatives remained—replace

the tank or try protective finishes.

Coatings based on BAKELITE Vinyl Resins were recommended and applied by spray, after sandblasting. That was over two years ago. *No further corrosion trouble has been experienced, and the coating is still in excellent condition.*

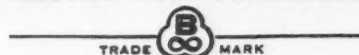
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folds of the type used in diesel engines are proving satisfactory in the field and replace Type 321 showing a saving of 2.5 lb. of nickel and 4.5 lb. of chromium.—INCO. 7012

5.3.2, 8.1.2

Color and Long Service With Terne Plate Roofing. *Lead*, 19, No. 3, 4-5 (1953).

The toughness of steel and the extremely high corrosion resistance of lead are combined in terne plate to produce one of the strongest, lightest, and most durable roofing materials. Thoroughly waterproof, hailproof, and undamaged by windstorms, terne plate roofing with occasional repainting gives decades of service.

Terne plate is made by dip coating sheets of steel with terne metal, an alloy of 80 percent lead and 20 percent tin. Expansion and contraction of the roofing due to temperature changes is negligible—0.8-inch per 100 feet for a 100 degree F variation. Terne roofing is preferably installed over wood sheathing such as $\frac{3}{8}$ -inch plywood covered with rosin-size building paper but not with tar paper or other acid-containing products. The plate is installed in continuous strips from ridge to eaves and held in place by separate cleats nailed to the roof. The edges of two strips and the vertical part of their cleats are folded over to make a 1-inch seam, which can be flattened and, if desired, soldered.

For terne plate roofs in most areas, white lead-in-oil or good-quality slow-chalking titanium-zinc house paints provide good appearance, long life, unlimited color choice and a sound surface for repainting. In industrial areas, a paint system of red lead primer under a suitable colored top coat results in less frequent need for repainting and lowers maintenance costs.—PDA. 7069

5.3.2, 8.4.3

Oil Derricks off Gulf Wear Leggings for Corrosion Protection. *Oil Gas J.*, 51, No. 42, 196 (1953) Feb. 23. *Steel*, 132, No. 6, 132 (1953) Feb. 9.

As protection against salt water and spray, oil derricks in the Gulf of Mexico wear leggings made of Monel for protection against gnawing corrosion. Illustrations.—INCO. 7104

5.3.3

Factors Influencing the Selection of (Electroplated) Metal Finishes. A. W. WALLBANK. *Sheet Metal Inds.*, 30, No. 315, 585-588, 590 (1953) July.

An introduction to the problem of selection and specification of metal finishes. The four factors of cost, service performance, appearance and physical effect of electrodeposited finishes are discussed. The advantages and disadvantages of zinc plating are described and the relative merits of cadmium and zinc for plating purposes are discussed with particular reference to their anodic deposits on steel.—ZDA. 7183

5.3.4

Recommended Practices for Metallizing. Part IB: Application of Aluminum and Zinc for Protection of Iron and Steel (Tentative). American Welding Society, New York, 1952, 10 pp.

A description of the procedures employed in metallizing surfaces with zinc and aluminum is presented, where these procedures are suitable to protect iron and steel against corrosion. The discussions apply to the application of metal

in wire form by gas metallizing only and represent the various practices and methods currently used in industry. Sections include: surface preparation, metallized bonding coat, zinc and aluminum coatings, additional protective measures, inspection and typical coatings for various exposures.—ALL. 6716

5.3.4, 5.3.2

Silver and Gold Plated Parts Meet Tough Specifications. T. C. DU MOND. *Materials & Methods*, 36, No. 5, 114-115 (1952) Nov.

Extremely small parts are being successfully plated with gold and silver using the barrel method. Care is exercised in cleaning the metal and removing scale before plating. The coatings are 0.0002-0.0007-inch thick and uniform, meet close tolerances and pass rigid adhesion tests. Silver is specified as plating material because of its excellent electrical conductivity, its resistance to corrosion and its lubricating and anti-galling properties. Gold is chosen primarily for its corrosion resistance, but it is also a fair conductor of electricity.

Plated parts pass bend tests in which the base metal is bent to the point of cracking. When the joint of an electrical connection wire soldered to a plated surface is pulled to rupture, only the solder ruptures, the plated coating does not pull loose. The plating withstands temperatures above 500 degrees F without blistering, lifting, or cracking. Plating adheres even when chipped with a chisel, stands up under crimping and does not lift or blister when soldered.

Materials that have been successfully plated include beryllium copper, tellurium bronze, teflon bronze, leaded brasses, carbon and alloy steels including the highly refractory 25-14 stainless steel and some aluminum and zinc base die castings.—PDA. 6822

5.3.4, 7.2

Protection of Tubular Structures from the Weather by Metallizing. A. CLIFT. *Metal Progress*, 62, 100-104 (1952) Nov.

No corrosion of the internal surfaces of tubular structures is likely, so long as all the tubes are sealed. External surfaces can be protected by hot dip galvanizing before erection; any damage caused by fabrication or welding can then be repaired by spraying with zinc. Alternatively, the tubes can be sprayed with zinc or aluminum before fabrication and again damage at welds can be repaired by hand spraying.—ZDA. 6706

5.3.4

Vacuum Metallizing and Plating—A Comparison. ISIDORE CROSS. *Metal Finishing*, 51, 59-63, 78 (1953) Dec.

Compares vacuum evaporation with electroplating. Illustrates limitations, advantages and applications of each. Photographs.—BTR. 7062

5.3.4

Current and Metal Distribution in Electrodeposition. Part III: Experimental Determination of Metal Distribution. J. KROSBEIN. *Plating*, 40, No. 8, 898-901 (1953) Aug.

Data obtained by measuring the metal distribution on the interior surfaces of right angle specimens of various shank lengths and fillet radii when plated in a specially designed shielded box at 2 average current densities in highly purified acid copper sulfate, Rochelle type copper cyanide and Watts' nickel baths

of conventional composition are presented. Information serves as a basis for estimating the relative metal distribution at various places on interior surfaces of recessed objects. Graphs.—INCO. 7074

5.3.4

Corrosion Prevention with the Metco Metallizing Systems. Metallizing Equipment Co. Ltd., Chobham, Surrey, 1953.

A series of technical data sheets describing various sprayed metal protective schemes and their uses. Zinc is recommended for rural, humid and sea-coast atmospheres, salt water immersion and to protect petrol and oil storage tanks and steel piling. For certain of these applications sealing coats based on vinyl or chlorinated rubber vehicles may be applied.—ZDA. 7180

5.3.4

Corrosion Protection by Means of Sprayed Metal Coatings. (In German). H. REININGER. *Werkstoffe u. Korrosion*, 4, No. 5, 156-172 (1953) May.

A review is given of instances of corrosion resistance of sprayed metal films. Density and adhesiveness of the coating are indicated as the main factors which determine the success or failure of the process. Practical applications of the metal-spraying technique. An effective coating can be obtained to resist rust, corrosion, or chemical attack by choosing an appropriate metal for spraying and the optimum thickness. One process uses a binary alloy of aluminum, zinc or magnesium to protect steel from rust; e.g. 70% aluminum + 30% magnesium was found to be very effective in an industrial atmosphere. A 0.0031-inch zinc sprayed layer gave about 5 years protection from rust in the industrial atmosphere of Sheffield and after 2 years immersion in sea water was almost unattacked. A zinc sprayed layer is also a good basis for the application of paints. A table is included giving the number of years during which less than 5 percent rust appears in various parts of the British Commonwealth on specimens zinc coated by various methods, including spraying, in thicknesses ranging from 0.001 to 0.028-inch. Photomicrographs, diagrams, photographs, tables. 83 references. 7219

5.3.4

Chromizing Improves Surface Properties of Steels. R. P. SEELIG. *Materials & Methods*, 37, No. 5, 106-109 (1953) May.

The Chromalloy process makes use of a gaseous chromium compound. Properties of the Chromalloy case (composition, thickness, hardness and wear, ductility), corrosion and heat resistance, effect on basis metals, costs and applications.—BNF. 7226

5.3.4

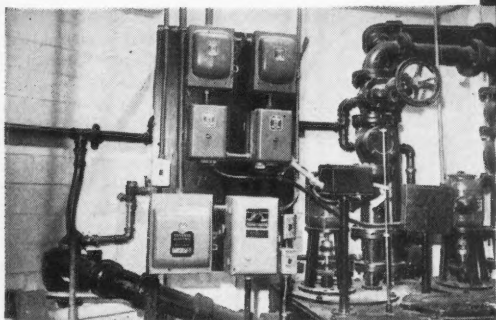
A Metallographic Study of Some Steels Used for Nickel Plating. A. E. R. WESTMAN AND F. A. MOHRNHEIM. *Plating*, 40, No. 12, 1366-1375 (1953) Dec.; *Proc. Am. Electroplaters' Soc.* (40th Annual Convention), 1953, 138-147.

Examination of a number of steels used for electroplating using various metallographic techniques (conical illumination, taper sectioning, phase contrast, and color photography). Chromium and nickel coatings which had failed in service were also studied and indicated that the basis metal may be a contributing factor. This is part of American Electroplaters' Society Research Project No. 14.—BNF. 7241

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FOR STATION CEILINGS—A single coat of paint based on Parlon gives excellent coverage, good reflectance to the station ceilings of Toronto's new \$50,000,000 subway. Ten-foot candles of light, glistening walls of bright-colored ceramic tile and stainless steel, and ceilings that will keep that "just painted" look, provide the subway platforms with a sparkling clean appearance.



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When planning was first begun on the new Toronto subway, more than 4 years ago, one problem was the selection of a suitable paint for station ceilings. After tests conducted with over 100 finishes, a paint based on Hercules Parlon (chlorinated rubber) was the choice.

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5.3.4

Tin-Zinc Plating Grows Up. *Tin and Its Uses*, No. 29, 9 (1953) Sept.

A review of the development of tinning plating since its introduction ten years ago. The coating combines the good properties of both metals. The plating anodes are usually cast with the composition tin 75% zinc 25%, but it is found that quite large variations in the proportion have little effect on the properties of the coating. European platers use an electrolyte of sodium stannate and zinc cyanide, while in America the potassium salt is claimed to give faster deposition. A considerable number of plants have been set up recently and the process is finding increasing application, particularly in the refrigerator, electronic and musical industries.—ZDA. 7258

5.3.4

Prevention of Corrosion by Metallizing the Surface. H. VANDERPOOL. *Metal Progress*, 64, No. 5, 161-164, 166, 168, 170, 172-173 (1953) Nov.

Gives examples of large-scale treatment of iron and steel with sprayed zinc or aluminum. Mentions the "Metcolizing" treatments (sprayed nickel-chromium, possibly followed by aluminum).—BNF. 7284

5.3.4

Metallizing of Glass, Ceramic and Plastic Surfaces. R. J. HERITAGE AND J. R. BALMER. *Gt. Brit. Telecommunications Research Establishment, Grey Malvern. Metallurgia*, 47, 171-174 (1953) April.

Three important metallizing techniques—reduction from aqueous solutions, reduction by heat and evaporation in a vacuum—are described and compared. Besides decorative possibilities for metallized glass, ceramics and plastic surfaces, there are important applications in the electrical and optical fields.

The success of reductions from aqueous solutions depends on complete removal of grease from the surface. Glass and ceramics can be cleaned with caustic alkali followed by nitric acid, plastics with noncorrosive organic reagents of mild alkalis. The surface is sometimes activated before coating. Metallizing by reduction from aqueous solution requires no elaborate equipment; it is particularly useful in electroforming where complex plastics or wax shapes are metal-coated followed by thick electrodeposits.

Firing methods depending on reduction on metal compounds by heat are limited to glass and ceramic bases. The value of the process is the great adhesion of the metal coat. Resistors made by engraving thin metal films of a gold-platinum mixture fired on glass or glazed ceramic surfaces are extremely stable and reliable. Resistors include a flat-plate form with a zig-zag film pattern giving high resistance in a small space, spiraled films on glass rods and metallized glass fibers of 0.001-inch diameter.

For evaporation coatings, a small amount of metal is usually heated electrically on a tungsten wire or spiral and vaporized in a vacuum of about 10^{-5} mercury. Only flat or slightly curved surfaces can be coated by this method and equipment is specialized.

Regardless of preparation, thin metal films can be thickened by numerous electroplating solutions. To prevent attack on the thin films, electrodeposition is usually started in a special bath followed by a normal plating solution. Poor adhesion is avoided by plating as soon as

possible after metallizing. Bath compositions for silver, copper and nickel plating on thin metallized films are given. Voltage should be applied before immersion of the object in the bath; heated solutions and strong acids and alkalis should be avoided.—PDA. 7307

5.3.4, 3.5.8

The Origin of Stress in Metal Layers Condensed From the Vapour in High Vacuum. H. P. MURBACH AND H. WILMAN. *Proc. Physical Society (London)*, 66, No. 407 B, 905-910 (1953) Nov.

Measurements are made of stress in deposits of nickel, iron, lead, gold, copper, silver, antimony, aluminum, bismuth, magnesium and zinc on copper strips. Stress is found to be characteristically of a tensile nature. Amount of stress is different for different metals. Diagrams, tables.—BTR. 7338

5.3.4, 4.3.1, 4.4.1

Chemical Plating. *Metal Ind.*, 82, No. 17, 329 (1953) May.

The General American Transportation Corporation of Chicago has developed a plating process known as "Kanigen," a process for plating the interior surfaces of tankers used in transporting corrosive chemicals. The process is based upon the reduction of nickel by hypophosphites and since it is a chemical process the racks and hangers may be of inexpensive construction. Special equipment is needed to maintain the solutions required. Pickling, rinsing and cleaning processes now in use in electroplating are more or less the same in the "Kanigen" process. This coating may be applied to aluminum, steel, copper, brass, bronze and stainless steel. Magnesium and plastics, when roughened by a chemical process, may also be plated by this method. Plate thickness is of high uniformity, being within 5 percent of the average as compared with electrolytic nickel, which may run from 25 to 200 percent between minimum and maximum. Adhesion is excellent and plated steel test specimens pulled to break point in tensile machines show no flaking or chipping of the plating. Corrosion resistance is superior to that of electroplating methods and it is claimed that the deposit is not likely to show any pores even at plating thicknesses of 0.0005-inch. Other properties include very low ductility, a coefficient of expansion of $13 \times 10^{-6}/^{\circ}\text{C}$ and electrical resistivity of approximately 60 microhms per cm. This process is expected to replace some industrial applications of electroplating and opens up new fields, as a controlled thickness to within 0.001-inch can be applied to large vessels, tanks, chemical process equipment, valves and pipe structures, which have been previously fabricated. High wearing qualities may extend the application to instrument gearing and precision manufacturing. A further important use may be in reclaiming small parts which have been machined beyond acceptable tolerances, thus salvaging expensive parts which would otherwise be rejected.—ALL. 6999

5.3.4, 8.8.5, 4.7

Notes on the Attack of Iron by Zinc. (In German.) R. HAARMANN. *Metal*, 7, No. 11/12, 406-412 (1953) June. *J. Iron Steel Inst.*, 176, Pt. 1, 119 (1954) January.

Review of problems arising in hot-dip galvanizing, under the headings of erosion, pitting and grain-boundary attack of steel pots by molten zinc. Effect of

composition of steel and zinc, temperature and time. Types of attack are shown by 20 photographs.—INCO. 7016

5.4 Non-Metallic Coatings and Paints

5.4.2

Relation of Bubble Structure of Porcelain Enamel to Fish-Scaling. C. G. BERGERON. *J. Am. Ceram. Soc.*, 36, 373-376 (1953) Nov.

Results indicate that the bubbles which were effective in inhibiting fish-scaling were contained approximately in the 1-mil layer of glass adjacent to the steel. Diagrams, micrographs, graphs, 5 references.—BTR. 7054

5.4.2, 2.2.2

Resistance of Porcelain Enamels to Weathering. D. G. MOORE. *Nat. Bur. Standards. Am. Soc. Testing Materials*, Preprint No. 92e, 1953, 8 pp.

Study of the weather resistance of porcelain enamels has been under way at the National Bureau of Standards since 1939. 768 1-ft.-square steel panels are being exposed at 4 locations selected to represent temperate residential, temperate industrial, temperate salt-air and semi-tropical residential. Results obtained show that most enamels are highly resistant to deterioration under the conditions existing at selected locations and that those enamels that are not resistant can be eliminated prior to installation by simple laboratory tests. Results of an inspection made after seven years of exposure are given. Tables, graphs, 10 references.—INCO. 7100

5.4.2, 3.5.9

Ceramic Coatings: Recent U. S. Developments for Extending the Life of High-Temperature Alloys. *Aircraft Prod.*, 14, No. 161, 107-108 (1952).

A brief review of recent U. S. developments on ceramic coatings for extending the life of high-temperature alloys by protecting them against scaling and intergranular corrosion. Details of the composition and application of a recently developed coating (high-barium, alkali-free frit with 30 percent chromic oxide) are given.—MA. 6713

5.4.2, 2.2.2, 3.5.9, 4.3.2

Symposium on Porcelain Enamels and Ceramic Coatings as Engineering Materials. 1953, 122 pp. Am. Soc. Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per Copy—\$2.00.

Among the many technical papers printed are some on corrosion resistance of ceramic coatings. Some Examples of the Functional Use of Porcelain Enamel and Ceramic Coatings by G. H. Spencer-Strong explains the various enamels and their corrosion resistance to various environments. The paper Resistance of Porcelain Enamels to Weathering, by Dwight G. Moore, relates the results of test panels exposed for seven years by the National Bureau of Standards in four locations. Data and information on the corrosion resistance of glass fused to steel is given in a paper, The Chemical Resistance of Glass Fused to Steel, by E. A. Sanford and O. J. Britton. Exposure to hydrochloric acid, nitric acid, sulfuric acid and phosphoric acid at temperatures above 212 degrees F and specific instances where glassed steel is being used in severe services are cited. The acid resistance of porcelains is also



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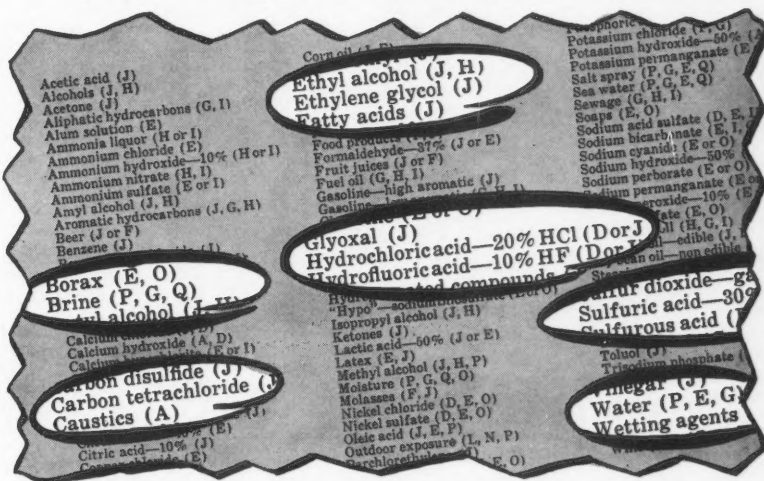
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considered in another paper, Acid Resisting Properties of Porcelain Enamels, by Harold C. Wilson.

Other papers treat of the abrasion resistance of porcelain and use of the material in high temperature jet engines. 7123

5.4.2, 3.5.9

A Laboratory Evaluation of Ceramic Coatings for High Temperature Applications. S. J. KETCHAM. Naval Air Materiel Center. Paper before ASTM, 56th Ann. Mtg., June 28-July 3, 1953. Am. Soc. Testing Materials, Preprint No. 92c, 1953, 8 pp.

Investigation to determine resistance to thermal shock, protection against oxidation of the base metal and adherence of ceramic coated test specimens of AISI 321 stainless steel and AISI 430 steel. The 321 specimens were tested at 1800 degrees F and the 4130 specimens at 1200 degrees F. Results of these tests indicate that one coating for 321 stainless steel was superior to the others tested and two coatings for 4130 steel appear promising. Results of thermal shock, oxidation resistance and adherence tests are discussed. Illustrations.—INCO. 7090

5.4.2, 3.5.9

How to Make Steel Last Three Times as Long. FRED B. SHAW. *Am. Machinist*, 97, 97-99 (1953) Dec. 21.

Ceramic coatings help protect against "hot spots" when metals are exposed to high temperatures and produce a surface smoothness that has minimum resistance to flow of hot gases. Photographs.—BTR. 7294

5.4.3

New Resin Linings Give Better Container Protection. DAVID E. HARTMAN. *Iron Age*, 171, 129-132 (1953) June 11. Describes various linings and points to consider when selecting. Photographs.—BTR. 7008

5.4.5

Some Causes of Paint Failure. E. JOHNSON. *Product Fin.*, 6, 53-57, 106 (1953) April.

Reviews faults which can be attributed to incorrect techniques, improper use of equipment, or poor pretreatment of the surface to be painted.—MR. 7085

5.4.5

Protective Coating. Is Flexible to —45°. *Machine Design*, 25, No. 3, 180 (1953) March.

Properties of a highly abrasion resistant resilient rubber-like coating, Cycloflex No. 7731, which protects metal parts from corrosion and abrasion, resists oils, greases, acids, alkalies, salts and petroleum solvents and can be applied by dipping and baking in coatings 1/32-1/2 in. thick. Manufactured by Murray Products, Inc.—INCO. 7127

5.4.5

Polymerization of Drying Oils by Heat. Parts I & II. WILLIAM BRUSHWELL. *Am. Paint J.*, 38; 74+, 68+ (1953) Dec. 7, Dec. 14.

Part I: Covers polymerization of simple molecules, linoleates, eleostearates, linolenates; polymerization rates and practical applications of thermal polymerization. Diagrams. 22 references.

Part II: Covers polymerization of eleostearates monocylic dimer formation bicyclic dimer and cyclic monomer formation polymerization of linolenates polymerization rates, practical applications of thermal polymerization, conjuga-

tion of oils and dimer acids. 20 references.—BTR. 7162

5.4.5

Metallic Soaps in Paints, Varnishes and Lacquers. R. E. WENDT. *Official Digest Federation Paint & Varnish Production Clubs*, No. 344, 604-617 (1953) Sept.

A survey of recent developments in the applications of metallic soaps in the protective coatings industry. New developments with zinc soaps have mostly been connected with the use of zinc stearate as a sanding aid for lacquer sanding sealers. A water dispersible form of zinc stearate has also been developed for the rubber industry where it is used in the dusting of uncured rubber stocks to prevent sticking. This form of zinc stearate can also be used in water paints as a waterproofing agent.—ZDA. 7185

5.4.5

Reflectivity of Aluminum Pigments and Paint. Part II. F. B. RETHWISCH, G. M. BABCOCK, AND E. C. RIGGS. *Paint, Oil, Chem. Rev.*, 116, 22, 24 (1953) Nov. 19.

Presents results of experimental studies on pigments from coarsest to finest, both paste and powder form. Results are a function of vehicle characteristics, pigment concentration and spraying technique. Tables.—BTR. 7217

5.4.5

Changes in the Colour, etc., of Films of Varnish, Paint and Similar Materials. H. RABATE. *Trav. Paint.*, 8, No. 2, 33-35 (1953).

Changes in paint films, etc. are classified under: total change (cracking, chalking), uniform change from original color and non-uniform change from original color.—RPI. 7224

5.4.5

Corrosion and Plant Maintenance. JOE RENCH. *J. Am. Oil Chemists' Soc.*, 30, 571-574 (1953) Nov.

Describes components of paint and characteristics of each ingredient justifying its use. Discusses application of paint in combating corrosion.—BTR. 7328

5.4.5

Neoprene Protective Coatings. *Can. Paint & Varnish Mag.*, 26, No. 6, 8, 10 (1952).

The use of a new type of neoprene, capable of giving solutions of solids content 60-70 percent but of low viscosity, as a protective coating for tanks, drums, etc. subjected to corrosive conditions is described. An accelerator is added before application and the coating will dry in 24-48 hours. Neoprene films do not adhere well to metal and it is necessary to employ a primer based on chlorinated rubber.—RPI. 6682

5.4.5

Weathering of Some Organic Coatings. E. J. DUNN, JR. *ASTM Bull.*, No. 182, 23 (1952).

There are perhaps thirty types of physical and chemical changes going on within a paint film as it weathers. Good weathering of a paint film requires an unusual balance or compromise of these physical and chemical forces. Many of these forces have been measured and the rate of change of these forces in the aging film appears to dictate the useful life of the film. The importance of such factors as relative humidity, uniformity

of film, film thickness, film shrinkage, moisture sorption, pigmentation, amount of film applied and physical structure on film properties are illustrated. Graphs are presented to illustrate the changes in some of the physical properties as the film ages. To eliminate confusion where many film properties are summarized, a numbering system is suggested as a means of attempting a single over-all film rating figure for comparing the integrity of films.—RPI. 6675

5.4.5

Asphalt Undercoating. *Chem. Eng.*, 59, No. 12, 234, 236 (1952) Dec.

Tough, sprayable black-asphalt material called EC-1189 used to protect metal buildings in fertilizer, paper pulp, plywood and chemical plants. It also protects the exteriors of storage tanks, tank trucks and railroad cars against spillage and water and soil corrosion. Manufactured by Minn. Mining & Mfg. Co.—INCO. 6654

5.4.5

Colored Silicone Finishes. M. A. GLASER AND E. MILLER. *Midland Ind. Finishes Co. Product Eng.*, 24, No. 3, 167-174 (1953) Mar.

Successful development of silicone coatings in color opens up significant new fields of application for designers and engineers throughout the metal-working industry. Properties of colored, heat-resistant silicone finishes, comparison with alkyd-melamine base enamels, recommended applications for various classes of industrial equipment and consumer products are included. Silicone paints have good chemical resistance with the exception of organic solvents and are applied by conventional methods such as spraying, dipping, brushing and roller-coating. Tables.—INCO. 6328

5.4.5

Red Lead and Lead Cyanamide as Rust-Preventing Pigments. R. HAUG AND W. FUNKE. *Farbe u. Lack*, 58, No. 9, 397-401 (1952).

The water-absorption properties of these pigments in various formulations are described. Usually, paints containing red lead have the lower water absorption. The effects of seawater and an atmosphere containing sulfur dioxide are described.—RPI. 6781

5.4.5

Rust-Inhibiting Paints. A. FOULON. *Deutsche Farben-Z.*, 6, No. 11, 457-460 (1952).

A review of modern developments in the field of anti-corrosive paints. Details are given of new types of media and pigments (e.g., barium, lead titanate, micaceous iron ore paints containing dispersing agents, etc.), but no references are included.—RPI. 6779

5.4.5

Pretreatment Etch Primers of the Single-Solution Type. E. E. HALLS. *Ind. Finishing (Brit.)*, 5, Nos. 52, 53 & 54; 185-186, 188-189; 286-292; 367-372 (1952).

Three single-solution type etch primers were evaluated, using aluminum and brass test panels, in comparison with a good two-solution type. Both air-dried and stoved sprayed single coats were examined, also with air-dried and stoved single finishing coats. Test conditions comprised severe wet heat and salt-spray exposure. The best single-solution type etch primer did not reach the standard of the



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two-solution type, but its performance could be enhanced by stoving. Can storage for six months at room temperature did not noticeably affect their quality.—RPI. 6783

5.4.5, 1.5

How (Non-Metallic) Protective Coatings Fight Corrosion. *Chem. Eng.*, 59, No. 12, 143-190 (1952) Dec.

This is a series of articles dealing with the use of paints and organic materials as corrosion-resistant coatings, dealing with the coatings rather than the basis metal. There is a directory of materials including metals and alloys, giving compositions, producers and applications in the chemical field.—BNF. 6678

5.4.5, 2.3.6

Pore and Blister Formation in Paint Films. J. D'ANS, K. WEKUA AND K. ULBRICH. *Farbe u. Lack*, 58, Nos. 9 & 10, 387-395; 431-435 (1952).

A microscopic method has been developed for investigating the pore and blister formation in lacquer films by means of a micro-cell which allows observation of a liquid film during drying, the microscope being in a horizontal position. It has been ascertained that bubble formation is due to the oversaturation of air dissolved in the lacquer adsorbed on dust particles by capillary action. On solvent evaporation these bubbles detach from the particle and migrate to the surface. This migration might cause pore formation. An increase of medium leads to pore reduction. The effect of moisture in the air, a moist substrate and surface structure of the base on pore and bubble formation has been studied. The influence of foreign matter, such as coal and glass dust, pigments, etc., is illustrated by micrographs. Investigations of microtome sections of film suggest dependence of pore size and shape on the chemical composition of the film.—RPI. 6756

5.4.5, 3.5.9

Selecting Special-Property Organic Finishes. A. L. ALEXANDER. *Naval Research Lab. Elec. Mfg.*, 50, No. 2, 106-109 + (1952) Aug.

Product design engineer now has at his disposal specialty coatings based on the newer resins, such as the silicones, epoxies and the fluoro-carbon which impart to the end product such performance values as high-temperature stability and outstanding corrosion resistance. Some of the products described require specialized application and production techniques. Coatings based on silicones and R-108 Intermediate do not require any special application techniques and are readily applied by conventional methods. Graphs, tables and 11 references are included.—INCO. 6318

5.4.5, 5.9.2, 5.9.3

Protecting Metal Surfaces with Paint. A. G. GRAY. *Metal Progress*, 62, No. 2, 79-81 + (1952) Aug.

In order to protect a metal surface successfully with paint, it is essential to prepare the surface properly before painting. The author discusses various methods of cleaning metals, including grit and shot-blasting, wire brushing, flame conditioning and chemical methods. The theory of paint protection and effect of electro-potential gradients are then considered and the article concludes with a section on the selection of pigments. Tests in various vehicles by

the American National Association of Corrosion Engineers showed that zinc chromate, zinc tetroxychromate, zinc oxide and red lead produced consistently good results. Zinc tetroxychromate, red lead, zinc dust and aluminium powder are recommended for use in polyvinyl butyral-type vehicles.—ZDA. 6767

5.4.5

Corrosion Prevention by Paints. J. E. O. MAYNE. *Trans. Inst. Metal Finishing*, 29, Advance Copy No. 2, 1953, 10 pp. *Bull. Inst. Metal Finishing*, 3, 19-28 (1953) Spring.

A discussion of the mechanism by which paint films prevent corrosion.

Paints can inhibit corrosion by modifying the anodic reaction. For this to occur the pigment must be either metallic, or soluble, or basic. Paint films are so permeable to water and oxygen that they cannot inhibit the cathodic reaction. In general they function by virtue of their high electrolytic resistance; they readily acquire a charge; consequently they are relatively impermeable to ions. Soap formation is beneficial, since it renders the film less permeable to electrolytes. The soaps also yield soluble degradation products, which suppress the anodic reaction. 19 references. 7303

5.4.5, 1.6

Organic Protective Coatings. Book, 1953, 6 x 9 in., 387 pages. WILLIAM VON FISCHER AND EDWARD G. BOBALEK. Reinhold Publishing Corp., 330 West 42nd St., New York 36, N. Y. Per Copy, \$7.50.

The book consists of contributions from 18 authors from several industrial areas and technical organizations.

The contents include consideration of paints as an engineering material, a discussion of the pigment dispersion problem, use and function of anti-corrosive pigments, vinyl resins, aminoplast resins, hot spray lacquers, formulation of emulsion and latex paints, synthetic resins and silicone resins. Other topics, not related to corrosion, are covered also.

The chapter on metal protection with synthetic resin coatings by E. E. McSweeney, Battelle Memorial Institute, lists numerous data on the chemical resistance, application technique, surface preparation, permeability of films, and other significant information related to the topic.

The book is fully illustrated and includes an extensive topical index. 7293

5.4.5, 2.3.1, 2.1.2

Testing Organic Finishes and Interpretation of Results. C. O. HUTCHINSON. *Plating*, 40, 1255-1266, disc., 1266-1268 (1953) Nov.

Describes over sixty properties of organic finishing materials as a basis of evaluating coatings. Lists standard tests for most of these properties. Tables. 141 references.—BTR. 7006

5.4.5, 5.4.8

Esters of Titanium and Their Use in Paint. Part III. Formulation and Performance of Butyl Titanate Paints. J. WINTER. *J. Oil Colour Chemists Assoc.*, 36, No. 402, 701-708 (1953) Dec.

The formulation of butyl titanate paints with leafing pigments and some non-leafing pigments is described. The zinc dust formulation has been improved, and although zinc leaf has been tried, the grades available were too coarse, leading to reduced corrosion resistance but improved hardness. Butyl titanate

paints have been tested as heat resisting coatings and as protection for steel against corrosion by sea water. Some preliminary work on butyl titanate anti-fouling paint containing copper oxide and zinc dust is described.—ZDA. 7199

5.4.5, 7.2

Protective Coatings for Buried Pipes. A. R. PEARSON. *Chemistry & Industry*, No. 26, 639 (1953).

It is reported that the ease of application, adhesion, continuity and insulating power of coatings of bituminous paint (coal tar pitch in solvent naphtha) are improved by incorporating a few percent of a varnish made with tung oil. Further improvement may be obtained by giving the dried coat a wash with a slurry of wax (soft paraffin or beeswax) in kerosene, whereby residual pinholes are blocked and perfect insulation attained.—RPI. 7144

5.4.7, 7.5.2

Painting Metal Containers Electrostatically. SAM LOBOVICO. *Ind. Finishing*, 29, 26-28, 30-31 (1953) Feb.

Metal cleaning, rustproofing, infrared dry-off, electrostatic spraying of heated materials and convection oven baking in conveyORIZED setup for spraying protective coatings over inside and outside surfaces of two kinds of sheet steel containers. Photographs.—MR. 7140

5.4.7

Spray Application of Anti-Corrosive Paint to Iron Girders. R. KLOSE. *Ind. Lack-Betrieb*, 20, No. 9, 174-175 (1952).

A fully automatic machine for spraying iron girders in a continuous process is described.—RPI. 6789

5.4.10, 8.9.3

The Role of Fibrous Glass Mats in Pipeline Corrosion Control. R. W. FARRIS. Owens-Corning Fiberglas Corp. Paper before Tulsa Pipeliners Club. *Gas*, 29, No. 3, 104 + (1953) Mar.

Use of fibrous glass mats for the reinforcement of underground pipeline enamels or as the base mat for an outer wrap is described. The theory of the function of the fibrous glass and supporting test procedures are discussed.—INCO. 6301

5.4.10, 7.2

Pipe Protection With Unbonded Coatings. RICHARD SNEDDON. *Petroleum Engr.*, 25, D12, D14, D16 (1953) Feb.

Describes advantages of using two separate coats with no bond between, which neutralizes shear stresses and lateral shocks.—BTR. 7220

5.4.10, 7.2

Polyvinyl Chloride Tape Approaches Ideal Material for Pipe Protection. GEORGE M. CARTER, JR. AND T. J. SKOTNICKI. *Am. Gas J.*, 179, 14-15, 30-31 (1953) July.

Reviews requirements of preventing corrosion, properties of polyvinyl chloride and application to pipe.—MR. 7158

5.4.10, 8.9.3

On the Corrosion Protection of Pipe Lines. (In German). WILHELM OBERGER. *Elektrotech. u. Maschinenbau*, 70, 34-37 (1953) January.

The average life span of an unprotected iron pipe in the ground is about 2 years. It can be increased to 5 years with the aid of a bituminous paint coat and to 10 years or more by a thick layer

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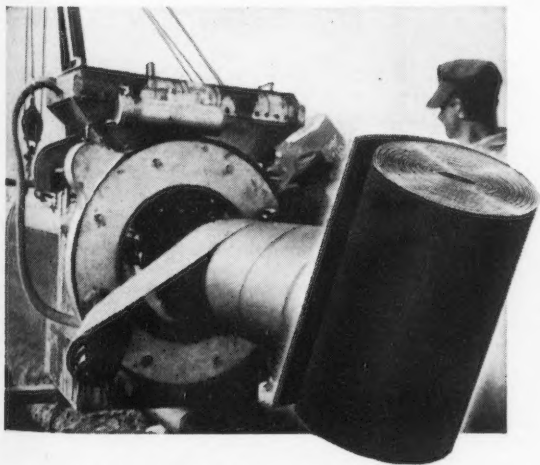
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of paint reinforced with fibrous materials. Cathodic protection further increases the life span.

In recent years glass fiber materials in conjunction with bituminous insulating compositions have given satisfactory results on many American and European oil and gas pipe lines. The supporting glass fiber web consists of fibers only 5-10 μ thick. These fibers have a tensile strength of 200 kg. per sq. mm., an elongation at break of 2%, and a 1:5 ratio of diameter to smallest bending radius. They are nonhygroscopic and withstand a temperature of several hundred degrees centigrade. The glass fiber insulation can be applied as a fabric, felt, or 'glass veil.' A suitable insulating material consists of tar-free tacky bitumen with a softening point of 80-90 degrees C.

The insulating material should constitute about 1.6 kg. per 100-mm pipe diameter per meter of pipe length. The amount of glass webbing should be 0.5-0.6 sq. m. to give a covering of 10-15 mm. The most favorable glass fabric width is approximately equal to the pipe diameter, for glass veils it is 33 cm. For a pipe of 250 mm diameter, 1.36 sq. m. of glass fiber material and 4 kg of insulating material per meter are required.—PDA. 7175

5.4.10, 8.9.3

Controlling Corrosion. A Manual on Underground Corrosion. Columbia Gas System Service Corp. *Oil Gas J.*, 52, No. 14, 133 (1953) Aug. 10.

Method of application of coal-tar and asphalt coatings is given. Asphalt coatings are less susceptible to impact and temperature changes, but they may be affected by absorption of small quantities of soil moisture or be dissolved by oil products contained in the soil. Coal-tar-base coatings are probably the most widely used pipe-line coating materials. A felt, asbestos or glass-fiber wrapper or a combination of wrappers are used over the enamel or coating while it is hot to prevent injury to the coating due to soil stresses produced as the backfill settles. Illustrations.—INCO. 7101

5.5 Oil and Grease Coatings

5.5.3, 7.1

Improving the Preservation of Metal Products. (In Russian). T. M. CHERNY-SHEVA. *Podshipnik*, No. 3, 15-19 (1953).

Test results established the superiority of unoxidized petroleum over technical vaseline and pressure greases as a means of protecting metal articles against corrosion. Ball bearings exposed to an atmosphere of 98-100 percent RH at room temperature showed no traces of corrosion at the end of 7 months when coated with petrolatum. In contrast, bearings coated with technical vaseline all showed traces of corrosion at the end of 7 months, 50 percent of them showing such traces at the end of 3 months and 80 percent at the end of 5 months. Another advantage of petrolatum is its slow rate of evaporation. At 100 degrees C the percent evaporation of petrolatum was only 0.20 at the end of 48 hours as compared with 0.30 for technical vaseline. An examination of the microstructure of the metal surfaces revealed that the granular structure of the specimens greased with petrolatum remained completely intact whereas those greased with technical vaseline and other greases had suffered substantially. In

addition to the fact that the protective properties of petrolatum are less dependent on the relative humidity and temperature of the air than are those of other types of greases, it is actually five to eight times more economical than technical vaseline and similar greases.—PDA. 7189

5.6 Packaging

5.6.3, 8.9.1

Aluminum Foil Protects Aircraft Parts. *Canadian Metals*, 15, No. 12, 48 (1952) Nov.

Aluminum foil, in combination with other materials, as used at A. V. Roe, (Canada) Limited, Malton, Ontario, is a moisture vapor proof barrier for the protection of aircraft components during shipping and storage. Protective wrapping consists of foil, plastic sheets and cotton scrim or kraft paper. Small items such as nuts and bolts are put into various sizes of bags made from the wrapping material. These are sealed automatically by rotary type heat sealer and have an inner bag lining of vinyl acting as a bonding agent. Several bags are packed in a cardboard carton which in turn is wrapped in a grease-proof wrapping dipped in a wax solution, wrapped in glassine paper, labelled and addressed. Landing gear, jet engines and oleo legs of the landing gear are also protected by aluminum foil material. A desiccant is placed inside the wrapping and can be inspected through a clear panel. One type of wrapping consists of a 1-mil thickness of vinyl film laminated to a 1-mil thickness of aluminum foil laminated to 1½-mil thickness of polyethylene, the whole mounted on cotton scrim. Metal containers are used for delicate parts such as flight instruments.—ALL. 6745

5.6.3

Volatile Corrosion Inhibitor Insures Rust-Free Die Sets. D. MEYER. *Producto Machine Co. Machinery*, 59, No. 12, 195-197 (1953) August.

Die sets shipped from Producto Machine Co. are packaged with a volatile corrosion inhibitor, called VPI. The powder vaporizes and the box cover acts as a barrier against the escape of the vapor. The corrosion inhibitor can also be coated on kraft paper and used as a wrap.—INCO. 7145

5.6.3

Protective Packaging. D. N. HAUSEMAN. Davidson Chem. Corp. *Ordinance*, 38, No. 199, 174-176 (1953) July-August.

New dehydration methods of storage help to protect reserve equipment. Method II packaging maintains the desired low relative humidity of 40 percent or below by containing the material to be protected within a barrier which is sealed against the entrance of moisture vapor. A desiccant such as silica gel is incorporated within the barrier. Complete details of the methods and materials used for military Method II dehydrated packaging are covered in specification MIL-P-116B.—INCO. 7159

5.6.3, 7.1, 5.4.5

Evaluation of Bearing Packages. WELLS E. ELITS, O. L. MAAG, AND M. J. BENACH. *Modern Packaging*, 26, 127-132+ (1953) May.

Discusses data from outdoor storage tests and laboratory accelerated tests of

MIL-B-131A Class A pouches, polyethylene containers, plastic strippable compounds and rigid metal containers of the food-can type. Photographs, tables.—BTR. 7050

5.6.3, 7.8, 7.7

Packaging of Wire and Wire Products. A. H. ANDREWS. *Wire and Wire Products*, 28, 572+ (1953) June.

Describes developments in packaging techniques to prevent rusting and damage.—BTR. 7118

5.8 Inhibitors and Passivators

5.8.2, 8.9.5, 7.1, 4.6.11

Device Inhibits Corrosion of Water Piping. *Marine Engineering*, 58, No. 7, 110 (1953) July.

Aqua-Clear feeders, developed by Durbury Laboratory, prevent rust and corrosion in manifolds and water jackets of Diesel and gasoline marine engines. As sea water is passed through the feeder, it picks up Aqua-Clear from the crystals in the feeder. The Aqua-Clear, in solution, deposits a microscopically thin glass-like air and water-tight protective film on the inside of pipes, water jackets, manifolds, etc., which prevents the water from touching the metal. Destruction by electrolysis is said to be controlled. Illustration.—INCO. 6944

5.8.3, 2.3.5, 3.6.8, 5.8.4

A Study on the Mechanism of Organic Inhibitors for Steel in Acid by the Measurements of Local Cell Polarization Curves. Y. HISAMATSU AND M. KANNO. *Japan Inst. Metals*, 17, No. 3, 149-152 (1953) March.

The local cell polarization curves of mild steel in 10 percent sulfuric acid with and without inhibitor at the temperature of 40 degrees C have been measured by two indirect methods.

The first is by the corrosion rate when a current from an external source is being applied, while the second is by the mixed potential and the breaks of the polarization curves when the external current is being applied. Inhibitors used were mainly 0.5 percent diethylaniline. It is shown that the corrosion of steel under such conditions is controlled by both the anodic and cathodic polarizations of the local cell, the former being greater and that the inhibitor affects both the anodic and cathodic polarizations of the local cell, the former being more strongly affected. This may be reasonably generalized to apply to many other organic inhibitors because most of them make the mixed potential nobler while the open circuit potential of the local anode is scarcely affected.—JSPS. 7163

5.8.4, 5.8.3

The Action of Polar Organic Inhibitors in the Acid Dissolution of Metals. NORMAN HACKERMAN AND A. C. MAKRIDES. Univ. of Texas. Technical Report to the Office of Naval Research [Contract Nonr-375(02)], October, 1953, 171.

Cathodic inhibition by polar organic compounds is considered to be the result of both physical adsorption and chemisorption. Electrostatic bonding at cathodic areas contributes to over-all inhibition. Polarization of anodic dissolution because of chemisorption of inhibitor is, however, more pronounced than cathodic polarization. Inhibitor chemisorption occurs through formation of coordinate co-

valent bonds with surface atoms of the metal, whereby the inhibitor acts as electron donor and the metal as electron acceptor.

This mechanism satisfactorily explains the dependence of inhibitive power on the electronic structure, solubility and substituents of the inhibitor, allows for differences between various metals and permits both positive and negative temperature coefficients.

The three prerequisites of an electrochemical mechanism of corrosion are a potential difference, a conduction path and availability of electrode reactions for transferring charges across the metal-solution interface. Mechanisms of inhibitors are discussed.—PDA. 7014

5.9 Surface Treatment

5.9.2

Modern Metal Polishes. M. A. LESSER. *Soap Sanit. Chemicals*, 29, No. 3, 157+ (1953) Mar.

A discussion on requirements, chemical action and odor of polishes and chrome polishes. The term 'metal polish' refers to products suitable for removing dulling tarnish, grease and soil from brass, nickel, copper and other metals. Liquid polishes are classified according to vehicle base: solvent, aqueous and emulsified. Polishes for copper, brass and nickel often contain a small proportion of ammonia which reacts with the oxides forming on these metals. Orthodichlorobenzene, introduced as a solvent and cleaner for metals, was reported effective on the oxides of nickel, silver, copper and aluminum but had a negligible effect on the metals. Baking soda and a silicone-containing product were advocated as a polish for stainless steel. Formulas, 26 references.—INCO. 7107

5.9.2

Metal Cleaning Equipment and Methods. JOHN E. HYLER. *Org. Finishing*, 14, 7-10 (1953) May.

Considers solution type, cleaning, vapor type degreasers, alkali cleaners, advantages of corrosion resistant coatings, cleaners for aluminum, oxide removal and storage of cleaners. Photographs.—BTR. 7005

5.9.2, 2.4.3, 5.3.4

A New Degreasing Evaluation Test: The Atomizer Test. HENRY B. LINFORD AND EDWARD B. SAUBESTRE. *ASTM Bull.*, No. 190, 47-50 (1953) May.

The American Electroplaters' Society sponsored a project entitled, Cleaning and Preparation of Metals for Electroplating, at Columbia University in 1949, to cover degreasing of metals. Steel is the material on which the study has been made. The authors have developed a new highly sensitive wettability test that may be readily applied under shop conditions. Also, the absolute sensitivities of the existing commercial degreasing evaluation tests have been determined and the sensitivities of wettability tests have been shown to be a function of the spreading rate of the soil in oil.—ALL. 7076

5.9.2, 3.2.3, 6.2.3, 5.3.4

A Study of Surface Oxides on Mild Steel Plates Intended for Galvanizing. (In French). J. VAN CAKENBERGHE, F. HALLA AND W. R. RUSTON. *Metaux: Corrosion Industries*, 28, No. 338, 406-409 (1953) Oct.

Ferrous oxide dissolves in pickling

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acid much more rapidly than ferrosferric or ferric oxides. The concentration of ferrous oxide depends on the rate of cooling between 700 and 300 degrees C. The composition of the oxide layer after different rates of cooling from 700 degrees C was determined by an X-ray method. It was found that samples cooled at 40 degrees per min. from 700-200 degrees C were pickled ten times faster than those cooled at 10 degrees per hour.—ZDA. 7298

5.9.2, 5.9.3, 1.4

Metal Cleaning Bibliographical Abstracts. New Ed. JAY C. HARRIS, compiler. Book, 132 pp., 1953. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. \$4.25.

Material is presented in order to make published data on metal cleaning readily available to persons concerned with production, finishing and maintenance of metal products. Several hundred new references bring the work up to date on all kinds of metal and most types of processes.—MR. 7197

5.9.4

Phosphate Coatings on Steel Surfaces. H. A. HOLDEN. *Metallurgia*, 48, No. 286, 71-77, 90 (1953) Aug.

Phosphate coatings are used to prevent corrosion of steel components ranging in thickness and size from structural steelwork to light gauge steel fabrication and as lubricant carriers for assisting cold-working operations such as steel wire drawing, tube drawing, deep drawing and cold extrusion. Other important applications include treatment of bearing surfaces to reduce wear and their use for electrical insulation purposes. Phosphoric acid type processes, orthodox phosphate treatments and thick, thin and light-weight coatings are discussed. Illustrations, 19 references.—INCO. 7255

5.9.4

Phosphatizing Steel Surfaces. JOHN E. TRUMBOUR. *Organic Finishing*, 14, 26-29 (1953) Nov.

Discusses uses of phosphate coatings to improve paint bonding and prevent corrosion and methods of applying and evaluating coatings. Photographs.—BTR. 7264

5.9.4.

Phosphate Coating as a Pre-Paint. CARL S. RANKIN. *Western Machinery and Steel World*, 44, 98-100 (1953) Dec.

Treating metal surfaces with a phosphate coating prior to painting, assures a good clean bond between surface and paint. Phosphating also reduces chemical reaction when protectiveness of paint is removed. Micrographs, photograph.—BTR. 7211

5.9.4, 6.4.4, 6.3.19, 6.3.2

Anodic Formation of Coatings on Magnesium, Zinc and Cadmium. KURT HUBER. University of Bern. *J. Electrochem. Soc.*, 100, 376-382 (1953) August.

The growth of anodically formed coatings on magnesium, zinc and cadmium in sodium hydroxide and carbonate solutions was followed by means of x-ray and electron diffraction and electron microscopy. Depending on the relative magnitudes of the solubility products, the coatings either remained in the form of oxides or were converted into the respective hydroxides or carbonates.

In the passivation of magnesium in sodium hydroxide solution, unstable

oxide is first formed on the surface of the electrode, which is later converted through the influence of the electrolyte into hydroxide. As a measure of stability, the respective solubility products differ by a factor of 10^5 .

On the active zinc anode, gamma-zinc hydroxide precipitates during treatment in sodium hydroxide solution. The initial product consists of oxide in sodium hydroxide as well as in sodium carbonate solution. Because the oxide and hydroxide are about equally insoluble, no subsequent conversion into the more soluble carbonate takes place. In the case of cadmium, the initial product formed in sodium hydroxide solution is unstable oxide, which is converted subsequently into hydroxide, because the solubility product of the hydroxide is about one tenth that of the oxide. Cadmium oxide is also formed as the initial product in sodium carbonate solution, followed by conversion into the carbonate.

A thick coating of the equilibrium product has some influence on the behavior of the electrode. It may produce a mechanical passivity in that the flow of current is hindered to some extent by an insulating material. The electrode behavior is, however, determined primarily by the thin, coherent, semiconducting film of the initial reaction product.—PDA. 7176

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.1, 3.7.2

The Economic Importance of the Rare Earths. J. LOMAS. *Machinery Lloyd* (Overseas Ed.), 25, 91, 93-94 (1953) Jan. 3.

Describes value of adding rare earths, cerium, lanthanum, neodymium, erbium, ytterbium, praseodymium, plutonium, samarium, europium, thulium, lutecium, gadolinium, terbium, dysprosium and holmium, to cast iron, alloy steels, stainless steel, tool steels, silicon steels and heat resisting steels. Includes superior mechanical properties, better resistance to corrosion, easier cogging and forging and higher electrical properties.—BTR. 7080

6.2.2, 3.2.3

Study of the Oxidation of High-Purity Iron and the Manner of Decomposition of the Monoxide Phase of Iron. (In French) R. COLLONGUES, R. SIFFERLEN, AND G. CHAUDRON. *Rev. met.*, 60, No. 10, 727-735, disc., 735-736 (1953) October.

Discusses structure of oxide films. Role of impurities in the mechanism of oxidation is described. Various mechanisms of the decomposition of the iron oxide phase are indicated. Graphs, micrographs. 11 references.—BTR. 7061

6.2.2, 4.7

The Attack of Iron by Molten Zinc Saturated with Iron. (In German) D. HORSTMANN. *Stahl und Eisen*, 73, No. 10, 659-665 (1953) May 7.

Investigation shows that attack of molten zinc on iron up to 490 degrees C and beyond 520 C follows a parabolic law, while in the intermediate temperature region it is a straight line. Below 490 degrees and above 520 degrees the alloy layers grow parabolically with time. The higher iron losses from 480 degrees and 490 degrees C and from 520

degrees and 530 degrees C are discussed and explained, as is also the straight line attack from 495-515 degrees C.—BNF. 7064

6.2.3, 5.8.4

The Inhibition by Quinolines and Thioureas of the Acid Dissolution of Mild Steel. T. P. HOAR AND R. D. HOLLDAY. *J. Applied Chem.*, 3, 502-513 (1953) Nov.

Dissolution of mild steel by warm sulfuric acid, with and without organic inhibiting additions, was studied by simultaneous measurements of corrosion rate and corrosion potential and by the determination of true anodic and cathodic polarization curves in the neighborhood of the natural corrosion potential. Graphs, diagrams, 25 references.—BTR. 7007

6.2.4, 3.5.8, 2.3.7

Propagation of Brittle Fracture in Steel. T. S. ROBERTSON. *J. Iron Steel Inst.*, 175, Pt. 4, 361-374 (1953) Dec.

Description of the development of a new test which applies a known transverse stress and assesses the material through its ability to arrest a running crack. Test results for 29 plates in 4 qualities of mild steel (all containing nickel) are discussed. The effect of plate thickness is investigated. Results of the new test and those of notched-bar tests on the same plates are compared. Physical properties of the plates tested, including chemical compositions are tabulated. Illustrations, tables.—INCO. 7223

6.2.5

How and Where To Use 430 Stainless. R. A. LINCOLN AND T. A. PRUGER. Allegheny Ludlum Steel Corp. *Iron Age*, 171, No. 9, 127-131 (1953) Feb.

All of the outstanding properties of series 300 austenitic stainless steels cannot be obtained when they are substituted by series 400 straight-chromium stainless steels. The latter do, however, perform satisfactorily where corrosion resistance is more important than high mechanical properties. Corrosion and oxidation resistance improve with increasing chromium content; however, increasing the chromium content of straight-chromium steels decreases their ductility.

Under mild corrosive conditions, such as exposure to dry or moist atmospheres, Type 430 will not be affected for long periods and will make a satisfactory substitute for 18-8 austenitic steels. Welds lower the resistance of Type 430 but show only slight attack after long, mild atmospheric exposure.

Under more severe conditions, such as high temperatures and acid fumes, Type 442 ferritic steel will perform as well as Type 302 austenitic steel if welding is not necessary. Satisfactory corrosion resistance can, however, be restored to Type 442 weld areas by proper heat treatment at 1450 degrees F.

The effect of finish, important in all stainless steels, is of more noticeable importance to Type 430 than to the more corrosion-resistant straight-chromium grades. Type 430 has best corrosion resistance when buffed or mill-finished with thorough scale removal by pickling. Rough-ground surfaces show greater susceptibility to corrosion.—PDA. 7067

6.2.5

New Stainless Alloy Fills Long Industry Need. N. F. MOTT. University of Bristol. *Iron Age*, 171, No. 25, 149-151 (1953) June.

V2B is a hardenable 18-8 (19-10) stain-

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less alloy containing approximately 2% copper, 3% molybdenum, 3% silicon, 0.5% manganese, less than 0.07% carbon and 0.1-0.2% beryllium. In the quench-annealed condition it is soft enough to be readily machined. After machining, the steel can be precipitation-hardened without distortion by a moderate heat treatment, and the resulting light heat tint can be readily removed. V2B can be cast as well as rolled.

The resistance of hardened V2B to sulfuric, hydrochloric and phosphoric acids and their salts exceeds that of all other precipitation-hardenable alloys. In nitric acid, V2B is also superior to the hardenable grades. Although it does not equal Types 304 or 316 in nitric acid, it resists all but the highest concentrations at boiling temperatures.

This excellent corrosion resistance, combined with high hardness and strength, erosion resistance and non-galling characteristics, suggests V2B for application such as valve disks, pump impellers, gears and other wearing parts, both at room and elevated temperatures. Unlike other precipitation-hardenable alloys, V2B does not over-age at elevated temperatures with resultant loss in hardness. It can, therefore, find application in steam accessories at temperatures up to 1400 degrees F.—PDA.

7068

6.2.5

Applications of Stainless Steel. W. L. NELSON. *Oil Gas J.*, 52, No. 15, 156 (1953) Aug. 17.

Uses of stainless steels are given. Steels used for corrosive conditions such as sulfuric acid, sulfur dioxide, carbon-black paste, butane dehydrogenation, fan blades, furfural regeneration, high-temperature condensers, naphthenic acids, low temperature, phosphoric acid, steam superheater, dilute hydrochloric acid and cavitation include Types 302, 502, 304, 316, 410, 347 and 317; 27% chromium iron, 27-20 chromium nickel steel, 18-8, 25-20 and 25-12 chromium-nickel steel. Ratio of cost of stainless steel equipment to the cost of equivalent carbon steel equipment is tabulated.—INCO. 7097

6.2.5

430 Stainless Is Hardy Civilian. A. H. THOMAS. *Armco Research Labs. Steel*, 133, No. 13, 88-89 (1953) Sept. 28.

With nickel-bearing steels still on the defense list, Type 430 passes outdoor corrosion tests with flying colors. One exception is severe marine atmospheres. Some of the stainless steel samples tested at the Middletown and Kure Beach corrosion yards are shown.—INCO. 7213

6.2.5

Nickel Restrictions Bring Use of New Stainless Steels. R. A. LINCOLN. *Iron Age*, 171, 129-132 (1953) May 14.

Describes development of possible chromium-manganese alternates to 18-8 Types 301, 302, and 304. Discusses mechanical and corrosion resistance properties.—BTR. 7106

6.3 Non-ferrous Metals and Alloys—Heavy

6.3.6

Arc Welding of Copper Using Copper Electrodes. (In Russian). P. T. DMITRIYEV, N. M. STEPANOV-GREBENNIKOV, AND N. I. MAKEEV. *Avtojennoe Delo*

(USSR) (Acetylene Welding), 23, 1-4 (1952) Aug.

Over 70 variations of coating composition were tested. Microstructures, mechanical properties and corrosion stabilities of the welds were determined.—BTR. 6761

6.3.13

Reaction of Tantalum With Hydrogen Chloride, Hydrogen Bromide and Tantalum Pentachloride; Action of Hydrogen on Tantalum Pentachloride.

RALPH C. YOUNG and CARL H. BRUBACKER, JR. *J. Am. Chem. Soc.*, 74, 4967 (1952) Oct. 5.

When hydrogen chloride gas was passed over tantalum metal at 419°C and above, white tantalum pentachloride formed and collected on a cold-finger condenser. When the temperature was elevated to 600 to 750°C, a thin film of metal, containing dissolved hydrogen, formed on the heated tube walls. After the reaction proceeded (600 to 750°C) for a few hours, it slowed markedly and an olive-colored powder (tantalum dichloride) formed on the surface of the unreacted metal. The tantalum dichloride powder (mixed with metal) was treated with 1 molar potassium hydroxide, and the residual tantalum was filtered away. When the solution was heated, hydrogen bubbled off, and a dark flocculent precipitate (presumably $TaO_x \cdot xH_2O$) formed. The metallic tantalum films were fused with sodium carbonate. During the fusion considerable adsorbed hydrogen gas escaped. When hydrogen bromide was passed over metallic tantalum at 375°C, tantalum pentabromide formed, and, if the temperature was maintained at 550°C or above, some tribromide began to form apparently mixed with a still lower bromide or perhaps the metal. At higher temperatures (up to 800°C) tantalum metal deposited in the apparatus, probably as the result of reduction or thermal decomposition of the penta- or tribromide. This reaction was also slowed by the formation of a green powder (tantalum tribromide) on the surface of the unreacted metal. Tantalum pentachloride was not reduced by the metal at 350 to 400°C in an evacuated tube. In the range 475 to 500°C, however, a small amount of a green chloride formed. The presence of some tantalum in a lower oxidation state (probably III) and possibly a compound such as Ta_2Cl_{10} is indicated. Tantalum pentachloride was not reduced by hydrogen at temperatures up to 400°C. However, if the reaction was carried out at 500°C, some reduction of the pentachloride did occur, and a film of the product, tantalum metal, containing dissolved hydrogen deposited on the heated walls of the reduction tube. No lower chlorides could be detected.—NSA. 5859

6.3.20, 6.3.8

Electrochemical and Polarographic Studies on the Corrosion of Zirconium in Presence of Various Aqueous Media; Progress Report. GEORGE B. ADAMS, JR., MARIO MARAGHINI, and PIERRE VAN RYSELBERGHE. Oregon University. June 12, 1953, 9 pp.

The anodic polarization of zirconium and of some of its alloys was studied over periods of time ranging from 6 seconds to several hours after dipping of the coupons into the solutions, and with ex-

ternal currents ranging from 0.5 to 2000 $\mu A/cm^2$. The evolution of the potential was also followed in the absence of external current. Solutions of hydrogen chloride, sodium carbonate, potassium chloride, and other salts were used at a temperature of 25°C. Two types of potential-time curves were observed according to whether the solutions did or did not contain Cl^- ion. A preliminary investigation of the polarography of the zirconium oxalate complex has been carried out.—NSA. 6249

6.3.20, 1.6

American Society for Metals. Zirconium and Zirconium Alloys. A Symposium Presented to Members of the A.S.M. during the Eighth Western Metal Congress and Exposition, Los Angeles, March 23 to 27, 1953. 9 x 6 in., 1953, 354 pp. American Society for Metals, 7301 Euclid Avenue, Cleveland 3, Ohio.

Contents: Oliver C. Ralston, "Zirconium Ores;" Herbert S. Kalish, "Preparation of Zirconium Powder;" M. A. Steinberg, M. E. Sibert, and E. Wainer, "The Extractive Metallurgy of Zirconium by the Electrolysis of Fused Salts;" W. M. Raynor, "Some Aspects of the Iodide, or Hot-Wire, Process for Manufacture of Zirconium;" S. M. Shelton and E. Don Dilling, "The Manufacture of Zirconium Sponge;" W. W. Stephens, H. L. Gilbert, and R. A. Beall, "Consumable-Electrode Arc Melting of Zirconium Metal;" R. B. Gordon and W. J. Hurford, "Fabrication of Zirconium;" W. L. Mudge, Jr., "Effect of Hydrogen on the Embrittlement of Zirconium and Zirconium-Tin Alloys;" R. K. McGeary, "Determination of Hydrogen in Zirconium by the Hot Vacuum-Extraction Method;" F. M. Cain, Jr., "Simplified Procedure for the Metallography of Zirconium and Hafnium and Their Alloys;" W. A. Bostrom and S. A. Kulin, "Recovery of Cold-Worked Zirconium;" G. R. Speich and S. A. Kulin, "The Solid Solubility of Tin in Alpha-Zirconium;" C. E. Lundin, D. J. McPherson, and M. Hansen, "The System Zirconium-Silicon;" D. J. McPherson and M. Hansen, "The System Zirconium-Tin;" E. E. Hayes and A. R. Kaufman, "Observations on the Alpha-Beta Transformation in Zirconium;" R. M. Treco, "Some Properties of High-Purity Zirconium and Dilute Alloys with Oxygen;" E. T. Hayes and A. H. Roberson, "The Zirconium-Nickel Phase Diagram;" A. H. Roberson and E. T. Hayes, "The Zirconium-Manganese Phase Diagram;" A. D. Schwope, "A General Comparison of the Metallurgy of Zirconium with That of Better-Known Commercial Metals;" Lex B. Golden, "The Corrosion-Resistance of Zirconium and Its Alloys;" Edward C. Miller, "Zirconium and Nuclear Reactors."—MA. 6296

6.4 Non-ferrous Metals and Alloys—Light

6.4.2, 3.7.3, 3.7.2

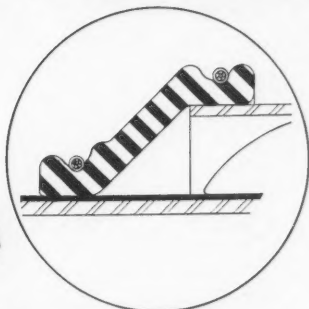
The Effect of Cold Work on the Microstructure and Corrosion Resistance of Aluminium-5% Magnesium Alloys Containing 0-1% Zinc. P. BRENNER, and G. J. METCALFE. *J. Inst. Metals*, 81, Pt. 5, 261-268 (1953) Jan.

The effects of cold work, of prolonged ageing at 70°C., and of additions of up to 1% zinc on the microstructure, corrosion-resistance, and stress-corrosion-re-

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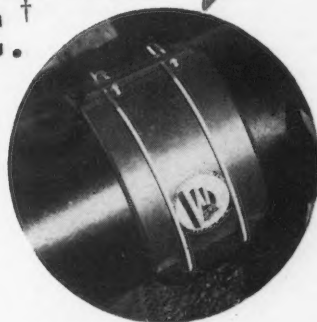
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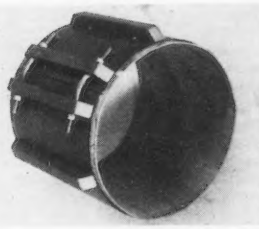
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sistance of an aluminum alloy containing 5% magnesium, have been investigated. The presence of zinc has little effect on the mechanical properties, but the alloy containing 1% zinc shows pronounced precipitation after ageing at 70°C., and corrosion attack is greater than in the case of the 0-0.5% zinc alloys, which show an incomplete grain-boundary network after ageing. Small amounts of cold work reduce the corrosion-resistance of the alloys appreciably, but heavy cold work both of aged and unaged materials results in a corrosion-resistance as high as that of unworked material. The maximum corrosion attack, at about 30% cold work, is associated with the presence of continuous grain-boundary films formed on ageing. Comparable behavior has been found in stress-corrosion tests, the maximum susceptibility to stress-corrosion occurring in material that has been given 30% cold work. Heavy cold work (50% reduction in thickness) produces material of high stress-corrosion-resistance. Explanations of the corrosion behavior are given. Photographs and 12 references are also given.—ALL. 6045

6.4.2, 3.7.2

The Influence of Impurities on the Resistance to Corrosion of Aluminum and Its Alloys. ERICH FRANKE. *Werkstoffe u. Korrosion*, 4, No. 1, 4-14 (1953) Jan.

It may be deduced generally from the results obtained from the present experiments that the resistance to corrosion of pure aluminum increases with the purity of the metal. The influence of impurities is determined by the type of corrosive medium to which the metal is subjected, and, frequently, the failure of aluminum may be due more often to the influence of operating or other exterior conditions than to impurities in the metal itself. As a result of the examination of the tendencies to corrosion due to the individual impurities and small additions of foreign elements, it has been found that iron and copper exercise a harmful effect, although the effect of the iron can be greatly reduced by the addition of manganese. Silicon in solid solution is absolutely harmless, but when it is eliminated in elementary form, the power of resistance of aluminum is reduced. Suitable heat treatment enables up to 0.5% silicon to be retained in solid solution. According to the latest investigations, the proportion of iron to silicon does not appear to be of particular importance to the resistance of aluminum in corrosion. Magnesium, lead, zinc and titanium in the amounts usually present in aluminum are harmless, but nickel is always injurious. Calcium and sodium, which often appear as impurities in aluminum obtained from certain ores, also influence the resistance to corrosion. The final conclusions obtained from the data on the influence of the addition of small quantities of other elements are, in most cases, not given, as the observations and results have mostly been obtained from single experiments, and, hence, do not offer sufficient material for the formation of conclusions, that might be of practical value.—ALL. 6080

6.4.2, 2.2.2, 3.5.8

Atmospheric Corrosion and Stress-Corrosion of Aluminium-Copper-Magnesium and Aluminium-Magnesium-Silicon Alloys in the Fully Heat Treated Condition. G. J. METCALFE. *J. Inst. Metals*

(England), 81, Part 6, 269-278 (1953) Feb.

The corrosion behavior of the aluminum alloys H10-WP and H15-WP in the extruded form has been determined in the stressed and unstressed condition by exposure to sea water, river water, and various natural atmospheres. The corrosion attack was assessed by visual and microscopical examination and by tensile tests on the corroded material. The most severe attack of both alloys resulted from exposure to the industrial atmosphere of Sheffield, where the average loss of strength after two years' exposure was approximately 11%, which is equivalent to a loss of thickness of 0.012 in. There was no indication of stress corrosion failure of either of the alloys at any of the exposure sites. The high stress corrosion resistance of the H15-WP alloy is somewhat surprising, since in sheet form the alloy is known to be very susceptible to stress corrosion failure. The absence of such failure is attributed to preferential attack ("foliation") occurring along grain boundaries and bands parallel to the direction of extrusion which re-distributes the concentration of stress at corrosion points. The rate of loss of strength of both alloys exposed at Sheffield, and of H15-WP alloy exposed to a marine atmosphere, was found to decrease with time, apparently exponentially. Scatter of the results from the remaining sites was appreciable, but it was clear that in general there was a decrease in the rate of corrosion with time.—ALL. 6164

6.4.2, 1.3

Aluminum Alloys—Properties of Material. F. R. BARNETT. *Australasian Engr.* (Australia), 44, 58-65 (1953) Feb. 7.

This is a general paper on aluminum covering its history, early and modern applications with specific details of its use in the chemical industry, its corrosion resistance and effects of specific environments on aluminum and finally surface treatment of aluminum and the various methods used.—ALL. 6215

6.4.2, 3.7.1, 3.2.2

Grain Boundary Attack on Aluminum in Hydrochloric Acid and Sodium Hydroxide. E. C. W. PERRYMAN. *J. Metals* (Trans. AIME), 5, No. 7, 911-917 (1953) July.

The wide grooves formed at the grain boundaries when high purity aluminum is attacked by hydrochloric acid or sodium hydroxide have been attributed by earlier workers to the high energy of the grain boundary material. The effect has been investigated for high-purity aluminum-iron alloys with up to 0.055% iron as a function of iron content and heat treatment. It is shown that the explanation given above is untenable, but that the results can be explained on the assumption that iron segregates to the grain boundary in solid solution. Materials used were in form of 0.064-inch sheet, which received a final cold reduction of 50%. The silicon contents are substantially the same (except for one) and with the same exception the copper contents are low and all of the same order. The first five materials can therefore be regarded as essentially a series of dilute aluminum-iron alloys of constant impurity.

Specimens 1 inch square were emery polished with metal polish, and annealed at 640°C for 72 hours. The examination of electrolytically polished

surfaces shows that the second phase observed here is the ternary aluminum-iron-silicon phase and not FeAl₃. Corrosion tests in 0.30N sodium hydroxide and 10% hydrochloric acid show that the rate of grain boundary attack is a function of: 1) the iron content, 2) the relative orientation of the neighboring grains and, 3) the rate of cooling from a high temperature.

Analyses of Materials

BNF Mark	Fe, %	Si, %	Cu, %
OCD	0.001	0.005	0.001
OCE	0.009	0.005	0.001
OCF	0.021	0.006	0.0005
OCG	0.037	0.007	0.001
OOB3	0.016	0.007	0.003x
OOB1	0.055	0.016	0.008x

x Determined by spectrographic analysis.—ALL. 6433

6.4.2, 3.7.2

Comparison of the Corrosion Resistance of 61S and AW10 Alloys and the Influence of the Addition of Copper or Zinc up to 0.5%. RIHEI KAWACHI. *Light Metals* (Japan), No. 7, 44-50 (1953) May.

Comparison of the corrosion resistance of 61S and AW10 alloy which are used as the heat-treatable aluminum alloys for marine service in America and England respectively and the influence of copper or zinc additions up to about 0.5% were examined. The tensile tests on the 1-mm thick specimens which were heat-treated to O, T4, T6 conditions were done before and after the corrosion tests namely, accelerated corrosion method, immersion in polluted sea-water, or stress corrosion. Results obtained are as follows: i) Performances of 61S and AW10 were so nearly the same that it was impossible to determine which was superior. ii) Corrosion resistance of these alloys is decreased with copper content, the degree of deleterious effect being greater on AW10 than on 61S. iii) Zinc additions produce little effect on either alloy. iv) The effects of chromium (0.25%) in 61S and manganese (0.7%) in AW10 are very similar, both increasing the tensile strength and improving the resistivity against stress corrosion when in the T6 condition.—ALL. 6412

6.4.2, 5.9.4

Chemical Oxidation of Aluminum for Decorative Purposes—Technical Notes Adapted from Replies Given by the Technical Enquiry Section. *Electroplating and Metal Spraying*, 6, No. 4, 133-135 (1953) April.

In answer to the query whether chemical oxidation processes for aluminum and its alloys can be used as decorative finishes and whether such coatings can be dyed the following conclusions are drawn. On small inexpensive articles and for application where sulfuric acid anodizing may be replaced by chemical oxidation treatments. M. B. V.-type coatings may be dyed, the best results being obtained on high purity aluminum or aluminum-magnesium (5-7% magnesium) alloys of small grain size. Work should be polished before oxidation, barrel polishing and chemical polishing being suitable. On many inexpensive self-color applications, the E. W. and V. A. W. processes will provide a cheaper substitute for sulfuric acid anodizing. In general, chemical oxide coatings are thinner and less resistant to corrosion and to wear than anodic

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6.4.2, 3.7.2

Importance of the Iron Content of High Purity Aluminium. M. METZGER AND J. INTRATER. *J. Metals*, 5, No. 6, 821-822 (1953) June.

The iron content of high purity aluminum, despite its very low figure, has a strong influence on a number of properties. In part, its influence is due to very low solubility of the iron-aluminum θ phase. For aluminum of about 99.99% purity, the iron content may be 0.001 to 0.004%. For values in this range, a second phase will be present below 410° to 480° C. This was determined by extrapolation of a log solubility versus inverse temperature plot of the solid solubility data. One consequence is the inhibition of grain coarsening below solubility limit. This is shown in a table which gives, for three iron contents, the annealing temperatures required for the absence of grains smaller than $\frac{1}{2}$ mm average diameter together with the minimum temperature for the presence of some grains larger than 2 mm diameter. Specimens were $\frac{1}{4} \times \frac{1}{2}$ -inch strips cut from hard rolled 1/16-inch sheet supplied by the Aluminum Company of America. They were annealed at 50° C intervals starting at 300° C. These tests were performed in connection with a study of the effects of iron on the intergranular corrosion of high purity aluminum in hydrochloric acid. It is found that aluminum of a given iron content treated at one temperature behaves like material of higher iron content at a higher temperature. The results indicate that the iron in solid solution has a strong tendency to segregate at the grain boundaries, probably because at sites in the boundary where the lattice is locally "compressed" stress can be relieved when the aluminum atoms are replaced by the smaller iron atoms. The behavior of grain boundaries even in relatively pure aluminum is strongly influenced by small amounts of other elements. Quantitative data obtained at temperature considerably below the melting point should not be considered as good approximations to the values characteristic of the boundaries in the ideally pure metal.—ALL. 6349

6.4.2, 3.2.2, 3.7.4

Grain Boundary Sliding and Mitigation and Intercrystalline Failure Under Creep Conditions. H. C. CHANG AND N. J. GRANT. *J. Metals* (Trans. AIME), Section 2, 5, No. 305-312 (1953) Feb.

Creep of very coarse grained, high-purity 2S and 3S (aluminum and aluminum-manganese) studied at 204°-593° C with an initial stress range of 50-1200 psi. A theory of the role of grain boundaries under creep conditions is presented, which is claimed to explain intercrystalline failure of commercial alloys. An optimum grain size should exist for good high temperature properties of high-purity materials.—BNF. 6514

6.4.2, 5.9.4, 4.2.5

An Example of the Use of Anodized Aluminum Parts in Architecture. (In German) H. NEUNZIG. *Aluminium*, (28, No. 5, 150-152 (1952) May.

A signboard which had remained untouched in a marine atmosphere for fourteen years was removed and examined. It was made of an aluminum-manganese alloy anodized with a coat-

ing about 4-microns thick. Raised letters consisted partly of brass and partly of the alloy aluminum-magnesium-silicon. The latter had an Eloxal coating about 20-microns thick and in addition was dyed either red or black. After removal of the 14-year-old coating of dirt, the ground plate showed spots of considerable corrosion. Although the letters had lost their coloring, they showed no other damage. Microscopic inspection showed the ground plate had corroded where aluminum-manganese crystallites had not been completely covered by the thin Eloxal layer. The aluminum-manganese alloy would have withstood corrosion much better if the anodic layer had been about 15 microns thick. More special value is placed on durable high polish than the use of Raffal or Reflectal alloy for the plate.—ALL. 6188

6.4.2, 2.3.9, 5.9.4, 1.6

Metallography of Aluminium and Its Alloys—Use of Electrolytic Polishing. P. A. JACQUET. Office Nat. Etudes et Recherches Aeronaut., Publication No. 51, 64 pp., 1952.

This report is divided into three main sections. The first section provides bibliographic references covering work done during the last three years on the physical chemistry of aluminum and its alloys with regard to electrolytically polished surfaces. The second section presents various data on modern micrographic techniques (preparation of the specimens, anodizing, etch figures). The third section describes the use of an automatic apparatus for electrolytic polishing which is suitable for obtaining micrographic samples of aluminum and all its alloys of homogeneous or polyphase structure.—ALL. 6814

6.4.2, 7.5.5

Aluminium Tanks and Pressure Vessels. E. V. SHARPBACK, Sr. *Products Eng.*, 26, No. 4, 183-185 (1953) April.

Aluminum tanks and pressure vessels are being used in the food, chemical, aircraft and transportation industries since they are light, corrosion resistant and readily designed and fabricated. A comprehensive table gives the dimensions, capacity, operating pressures and weight of aluminum single cylindrical tanks having spherical heads. The operation pressures listed are based upon a factor of safety of 4. The capacities of flat or conical bottom tanks can be readily determined by additional calculations. The accepted methods of supporting vertical and horizontal tanks are shown. Where the tanks are in contact with the ground or supporting materials other than aluminum, bitumastic coating must be applied to the contacting surface to prevent corrosion. Methods of construction and joining are illustrated diagrammatically.—ALL. 6500

6.4.2, 3.7.2

The Effects of Various Additions of Elements on the Tensile Properties and Corrosion Resistance of Aluminum-Magnesium-Silicon Alloy. HIROSHI TANKA AND EIICHI NAGAKUBO. *Light Metals* (Japan), 2, No. 6, 46-55 (1953).

The effects of silicon, chromium, copper, iron and manganese on the tensile properties and corrosion resistance of aluminum-magnesium-silicon alloy were investigated. In the experiments magnesium contents were varied as 1.0, 0.85

and 0.7% while silicon contents were varied from 0.4 to 1.0%. In the case when chromium, copper, iron and manganese were added, their amounts were 0.25, 0.25, 0.4 and 0.2% respectively. These alloys were annealed (0), quenched (500° C x 30 min.) and natural-aged (T4), quenched and tempered (175° C x 9 hrs.) (T6), quenched and rolled by 6% (T36). Corrosion tests were conducted for 6 months by means of wet-and-dry method in 3% sodium chloride solution. The results of the accelerated test by which the specimens were immersed in 3% sodium chloride + 0.3% hydrogen peroxide solution for a month are shown. The relative resistivities of the alloys were evaluated by measuring the decreases in elongation and analyzing them by "Analyzing of Variance." The effects of each element are given.—ALL. 6491

6.4.3

Properties of Beryllium. M. C. UDY, H. L. SHAW, AND F. W. BOULGER. *Battelle Mem. Inst. Nucleonics*, 11, No. 5, 52-59 (1953) May.

Survey of beryllium included production, atomic and nuclear, physical, chemical and mechanical properties, fabrication and applications. Beryllium corrosion was studied and in air, times for onset of severe corrosion were reported as 60 hr. at 700° C, 12 hr. at 800° C, and 1 hr. at 900° C. The oxidation was a grain boundary attack. Results of corrosion of beryllium in water suggested that pitting should be considered. Investigation of beryllium in liquid metals showed that at 600° C fine-grained beryllium was more readily attacked by gallium than was coarse-grained metal. No evidences of stress-induced corrosion in beryllium were found. Tables, graphs and 21 references.—INCO. 6530

6.4.4, 5.9.4, 5.4.5

New Process Makes Magnesium Corrosion-Resistant. *Products Finishing*, 6, No. 2, 75 (1953).

Formulae are given for three chromating baths for magnesium. A suitable following primer comprises a zinc-chrome-pigmented resin-based composition, over which an NC lacquer or synthetic resin enamel may be applied.—RPI. 6464

6.4.4

Magnesium Die Casting Ingot Offered. *Materials and Methods*, 38, No. 2, 144 (1953) Aug.

The Dow Chemical Co., Midland, Michigan, has announced the availability of a new magnesium alloy ingot, suitable for magnesium die casting. This alloy, designated as Dowmetal AZ91B, contains beryllium additions for lower melt loss and increased efficiency.—ALL. 6382

6.4.2, 3.7.3

The Electrochemical Properties of Pure Aluminum (Second Report). HIROMITSU HARIMOTO AND KATSUZO MIZUNO. *Light Metals* (Japan), No. 4, 68-70 (1952) Aug.

The first report dealt with the changes in electrode potential with respect to the purity of the aluminum used and the type of electrolytes. This paper reports results of studies concerning the effect on the electrode potential of pure aluminum by the degree of working. The aluminum specimens used were 99.6 per-

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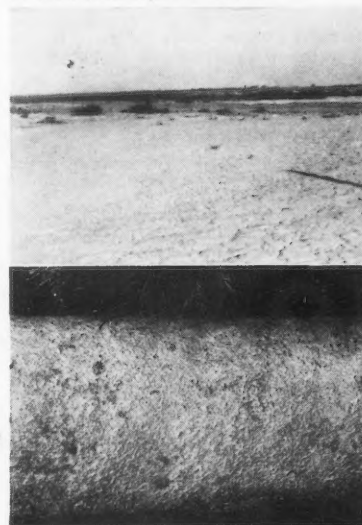
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cent purity. They were heat treated at 180, 350 and 450 degrees C and worked to 40 percent, 70 percent and 90 percent respectively. The electrolytes used were 3 percent sodium chloride + 0.1 percent hydrogen peroxide, 0.1 percent hydrochloric acid and 0.5 percent sulfuric acid. A vacuum tube potentiometer was adopted for use with this research and the following conclusions were reached: 1) at the instant of dipping the electrode potential was always electro-positive. 2) the electrode potential differs with the degree of working of the specimen. It becomes greater in proportion to the degree of working. 3) electrode potential differs with heat treatment. 4) with 3 percent sodium chloride + 0.1 percent hydrogen peroxide electrolyte, the electrode potential assumes a generally constant value with time. With 0.1 percent hydrochloric acid electrolyte there is a tendency for the electrode potential to keep dropping with time; with 0.5 percent sulfuric acid electrolyte the tendency is to rise with time.—ALL. 6815

6.4.2, 5.9.4

Flexural Fatigue Strength of Anodized 24ST Aluminum-Alloy Sheet. C. B. CLIEFF. Mississippi State College. *Aeronaut. Eng. Rev.*, 11, No. 12, 29-30, 42 (1952) Dec.

Effect of anodizing on the flexural fatigue strength of 24ST aluminum alloy sheet was investigated. Corrosive atmosphere and sulfuric-acid bath anodizing decrease considerably the fatigue properties of 24ST sheet and similar results can be expected for other alloys. While anodizing and painting of aluminum alloys result in improved corrosion resistance, this process should not be used in areas subject to fatigue or corrosion-fatigue. Curves show comparison of corrosion-fatigue and fatigue flexure strengths of polished and anodized and painted 24ST sheets.—INCO. 6653

6.4.2, 5.4.5

Painting Practice for Aluminium. Aluminium Development Association (London). Information Bulletin No. 20, 19 pp., 1952, Dec.

Broad survey which shows that painting of aluminum largely follows established practice for other metals with certain modifications to suit particular material. Also deals with cleaning and degreasing pretreatment where necessary, choice of paint system, single coat systems, multi-coat systems and repainting of small and large components and structures.—MR. 6711

6.4.4, 3.7.2

Preparation of High Purity Magnesium and a Study of the Effect of Non-Metallic and Alkali Metal Impurities on the Corrosion Characteristics of Pure Magnesium. Eleventh Quarterly Report Covering Period June 1, 1952-August 31, 1952, Dow Chemical Company, Metallurgical Labs., 26 pp., 1952.

Corrosion characteristics of the magnesium-iron-aluminum alloy system were studied to determine the iron tolerance limit in alloys containing 0.1 to 10 percent aluminum. A gradual increase in the corrosion rate was obtained upon going from 10 to 46 parts per million iron in the presence of aluminum or with aluminum increasing from 0.1 to 3 percent accompanied by 10 to 46 parts per million iron. A sharp rise in corrosion rate was observed when the aluminum content exceeded 3 percent. Alloys of

magnesium-iron-silicon, magnesium-iron-chlorine, magnesium-iron-carbon, magnesium-sulfur and magnesium-iron-sulfur were tested in a chamber designed to give exposure to air at 100 percent relative humidity and condensed water vapor. A metallographic examination of the magnesium-silicon and magnesium-iron-silicon alloys was undertaken to correlate the microstructures with the corrosion properties previously reported.—ALL. 6738

6.4.4, 8.9.1, 5.9.1

Cleaning, Dow Treating and Finishing Magnesium Products. JAMES D. BRENNAN. *Ind. Finishing*, 28, No. 11, 20-22+ (1952) Sept.

The finishing processes for magnesium aircraft parts as they occur at the Northrop Aircraft Company, are described in this article. Parts are degreased in trichlorethylene. Vapor temperature in the degreaser is controlled between 188 and 189 degrees F. The electrocleaning solution is made up of 4 to 6 oz. Anodyne (a commercial chemical) per gallon of water. No current is used in this operation. Temperature here is held at 185 degrees F. A hot rinse follows at 200 degrees F. Three surface treatments are used—Dow No. 1 being a chrome pickle which is employed for "in process" parts only. A sodium dichromate treatment (Dow No. 7) can be used on all magnesium alloys except those of the AMC-3S specification. A third treatment, known as Dow No. 10, is a sealed chrome pickle process and is accomplished by first applying Dow No. 1 treatment, a rinse and then following with Dow No. 7. The chrome pickle solution is composed of 1½ lb. of sodium dichromate per gallon of water and 1½ pints of nitric acid per gallon of water and is used at room temperature. It cannot be used on high precision machined parts as it removes 0.0006-inch of metal. The No. 7 treatment causes no dimensional changes. The MF acid solution used in the No. 7 treatment contains ammonium bifluoride as its active agent. Cleaned and rinsed parts are immersed from two to five minutes in this MF acid etching solution, then rinsed in cold water. Then they are completely immersed for from 30 to 45 minutes in a boiling sodium dichromate solution containing one pound of sodium dichromate and ¾-oz. of magnesium fluoride per gallon of water. Cold and hot water rinses follow. After surface treatment the parts are sealed with No. 75 Seal Primer, a modification of conventional zinc chromate primers. In assembling magnesium components, all steel and brass screws, bolts and nuts are cadmium plated and aluminum bolts and nuts are anodized. The procedure used in assembly of aircraft is reviewed.—ALL. 6823

6.6 Non-Metallic Materials

6.6.5, 7.2

Prestressed-Concrete Pipe Failure is Attributed to Wire Corrosion. *Eng. News-Record*, 150, No. 19, 24 (1953) May 7.

Failure of prestressed-concrete pipe installed for the water supply line of Regina, Sask., was due to corrosion of the prestressing wire. The corroding agent was probably calcium chloride used in the cement core and the cement cover coat. Sulfates present in the Regina

water had some influence as well. Investigators emphasized that highly stressed steel was more susceptible to corrosion than unstressed metal.—INCO. 6362

6.6.6

Study of Refractory Corrosion by Examining the Fluorescence of the Adjacent Glass. (In French.) M. JAUPIN. *Verres et Refractaires*, 6, 356-360; disc., 361 (1952) Nov.-Dec.

Results of laboratory and industrial observations are discussed. Physical and chemical actions of various media are explained.—BTR. 6661

6.6.6, 3.5.9

A Contribution to Present Knowledge of the Resistance of Sintered Alumina to Corrosion. GASTAV JAEGER AND ROLF KRAEMANN. *Werkstoffe u. Korrosion*, 3, No. 11, 401-414 (1952) Nov.

The present work contains, in part, some quantitative contributions on the resistance of crucibles made of compactly sintered alumina to corrosion when exposed to the action of aqueous solutions such as acids and bases as well as acid and basic reagents. In addition, details of numerous experimental fusions are given which show the behavior of sintered alumina (Degussit Al 23) at temperatures up to 1,800 degrees C in the presence of a number of substances which are of importance in industry. These substances include glass, slag, iron scale, as well as refractory and other materials.—ALL. 6664

6.6.8

Weathering Characteristics of Polyvinyl Chloride Type Plastics. J. G. HENDRICKS AND E. L. WHITE. *Wire & Wire Products*, 27, 1053-1957, 1126 (1952).

The paper includes general considerations in the compounding of vinyl plastics, factors affecting weathering characteristics and evaluation of natural and artificial weathering tests.—RPI. 6784

6.6.6, 1.3, 3.5.9

Corrosion of Refractory Materials. *Blast Furnace Steel Plant*, 40, 921-925, 927 (1952) Aug. (Translated by Helen Towers from *Berichte der Deutschen Keramischen Gesellschaft und des Vereins Deutscher Emailfachleute*, 29 (1925).

Chemical and physical factors, critical review of work done during 1940-1950. Scope is confined to work done in Great Britain with occasional references to American literature. Extensive reference to service in metallurgical furnaces. 26 references.—MR. 5932

6.6.6, 8.8.1

Fused Quartz. *Chem. Eng.*, 60, No. 4, 302, 304-305 (1953) April.

Applications in the chemical process industries, physical and mechanical properties, and the chemical resistance of fused quartz or silica are covered.—INCO. 6265

6.6.10, 8.6.3, 7.10, 6.2.5

Stainless Steel Tow Carts of All-Welded Construction. *Canadian Metals*, 16, No. 1, 42 (1953) Jan.

Stainless steel, which will not corrode or damage nylon thread, is used for making tow carts to be used in textile mills. The carts are produced in an all-welded construction, both automatic and hand welding being used.—INCO. 6282

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INDEX TO ADVERTISERS

Vol. 10 SEPTEMBER, 1954 No. 9

Allen Cathodic Protection Co.....	i
Alloy Steel Products Co., Inc.....	xiii
Amercoat Corporation.....	Inside Front Cover
American Chemical Paint Co.....	51
Apex Smelting Company.....	24
Atlas Mineral Products Company.....	19
Bakelite Company, A Division of Union Carbide and Carbon Corporation	41
Bart Manufacturing Company.....	32
Brance-Krachy Co., Inc.....	63
Carbolite Company.....	21
Cathodic Protection Service.....	xii
Cathodic Rustproofing Company.....	38
Coast Paint & Lacquer Co.....	47
Colonial Plastics Mfg. Co.....	9
Corrosion Directory.....	34
Corrosion Rectifying Company.....	2
Dow Chemical Company.....	ii, 8
Dresser Industries, Inc.....	x, xi
Duriron Company, Inc.....	Inside Back Cover
Earl Paint Corporation.....	33
Federated Metals Division, American Smelting & Ref. Co.....	23
Firestone Plastics Company.....	11
Gates Engineering Company.....	25
Haveg Corporation.....	31
Hercules Powder Company.....	43
Hill, Hubbell & Company, Div. of General Paint Corporation.....	53
Humble Oil & Refining Company.....	13
International Nickel Co., Inc.....	37
Johns-Manville Sales Corp.....	49
Koppers Company.....	35
La Favorite Rubber Mfg. Co.....	2
Mavor-Kelly Company.....	15
Mayes Brothers, Inc.....	18
Minnesota Mining & Manufacturing Co.....	64
Mutual Chemical Company of America.....	3
National Association of Corrosion Engineers.....	314, 4
National Carbon Company, Div. Union Carbide & Carbon Corp.....	57
Nelson Electric Manufacturing Co.....	22
Nicolet Industries, Inc.....	24
Offenhaus Company.....	36
Pipe Line Anode Corporation.....	16
Pipe Linings, Inc.....	59
Pittsburgh Coke & Chemical Co.....	xv
Polyken Products, Dept. of the Kendall Company.....	61
Positions Wanted and Available.....	6
Reilly Tar & Chemical Corporation.....	7
Rig Engineering Company.....	39
Service Engineers, Inc.....	30
Standard Magnesium Corporation.....	20
Standard Pipeprotection, Inc.....	vi
Stearns, D. E., Company.....	Back Cover
Tapecoat Company, The.....	29
Tnemec Company, Inc.....	12
Tretolite Company.....	xiv
Tube-Kote, Inc.....	26
United Chromium, Inc.....	45
United States Stoneware Company.....	vii
Williamson, T. D., Inc.....	55

6.6.11

The Evaluation of Wood Preservatives. Parts I & II. REGINALD H. COLLEY. *Bell System Tech. J.*, 32, 120-169, 425-505 (1953) January, March.

Part I. Offers a review and interpretation of laboratory and field experiments aimed at determining necessary protective threshold quantities of wood preservatives. Discussion of specific criticisms of techniques involved and replies to these criticisms are included. Presents a correlation of results obtained from soil-block culture tests, outdoor exposure tests on stakes and on pole-diameter posts as well as pole line experience. Photographs, graphs, and tables. 129 references. Part II. Reviews laboratory and field experiments to determine necessary protective threshold quantities of wood preservatives. Presents results obtained from soil-block culture tests, outdoor exposure tests on stakes, and on pole-diameter posts as well as pole line experience. Graphs and tables. 129 references.—BTR. 6294

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1

Lubricating Large Engines. B. CORRIGAN. Texas Co. *Diesel Power & Transportation*, 30, No. 12, 50-54 (1952) Dec.

A discussion on problems associated with lubrication of large gas, dual-fuel and Diesel engines includes cylinder lubrication, bearing corrosion which is mostly associated with bearings containing lead in the pure or alloy form, engine deposits and residual fuels containing vanadium, nickel, sodium and other compounds and engine wear which is probably caused by corrosion of piston rings and cylinder liner surfaces by corrosive vapors or acids and fuel contaminants such as sulfur and nitrogen compounds. Illustrations.—INCO. 6730

7.1

Role of Corrosion in Engine Wear. J. C. GENIESSE AND H. R. JACKSON. Atlantic Refining Co. Paper before Soc. of Automotive Engrs., Metropolitan Sec., New York, Oct. 16, 1952. *Petro. Proc.*, 7, No. 11, 1620-1622 (1952) Nov.

Work of various investigators is reviewed to show the influence of low temperature operation conditions and sulfur content of fuels on wear of cylinder wall and piston rings. Jacket temperature, oil, cylinder wall metallurgy and fuels are important variables in the corrosive wear of engines and the resulting high oil consumption. Engine wear from this cause can be reduced through proper selection of oil and control of jacket temperature. Graphs and references.—INCO. 6726

7.1.3.2.2

The Phenomenon of Erosion by Pitting, with Particular Regard to Tappets. (In Italian.) L. LOCATI AND A. FERRO. *Metallurgia Italiana*, 44, 448-455 (1952) Aug.-Sept.

Distribution of stresses during rotation was investigated, with special regard to pitting of steel and cast-iron tappet parts for internal-combustion engines. Mechanical properties of several types of carbon steel and cast iron heat

treated in different ways are tabulated.—BTR. 6684

7.1.3.5.9.1.3

High Temperature Alloys for Gas Turbines: A Review. H. V. KINSEY. *Canadian Metals*, 15, Nos. 11 & 13, 28+; 20+ (1952) Oct., Dec.

Requirements for materials for combustion chambers, nozzle guide vanes, turbine blades, discs or rotors; available alloys (ferritic-martensitic steels, austenitic alloys, recent alloys, including molybdenum and chromium-base and ceramics). 42 references.—BNF. 6787

7.1.4.4.7

Some Problems Associated with Lubrication of Large Engines. *Lubrication*, 38, No. 11, 137-48 (1952) Nov.

Engines discussed are large gas, dual-fuel and diesel engines. Cylinder lubricators, bearing corrosion, crankcase explosions, engine deposits and wear are investigated. Table lists the commonly used bearing materials; all but a few can be corroded as a result of oil deterioration. Bearing corrosion properties are given. Corrosion of engine is dependent upon fuel quality, completeness of combustion, jacket cooling temperature, exhaust back pressure and lubricating oil quality. Illustrations.—INCO. 6659

7.1.5.4.2

Ceramic Coatings: The Solaramic Process Applied to Gas-Turbine Parts. *Aircraft Prod.*, 14, No. 167, 305-306 (1952).

The Solaramic process for the protection of gas-turbine components is described. A thin vitreous or semi-matt ceramic coating is intimately bonded to the surface of the metal. The smooth surface of the coating offers minimum resistance to the flow of gases and, because oxidation is eliminated, protects the parent metal against cracking and warping. Data on other properties of the coating are given.—MA. 6712

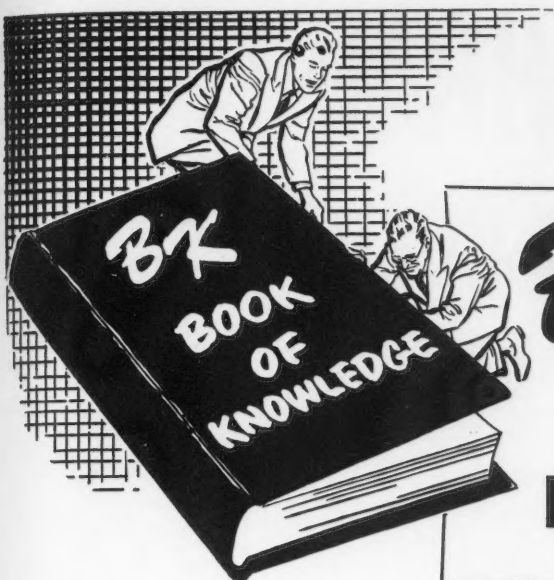
7.1.5.8.2

Prevention of Corrosion in Inactive Strut and Stern-Tube Bearings. R. C. FRANCIS. Naval Engineering Experiment Station, Annapolis, Md., Report No. 1A (2) 066744, March, 1952, 18 1.

The first phase of a long-term test of chromate, nitrite and combined chromate-phosphate corrosion inhibitors for submerged strut and stern-tube bearings of the inactive fleet was completed. Simulated bearings were kept for six months in test solutions diluted at various rates with synthetic sea water.

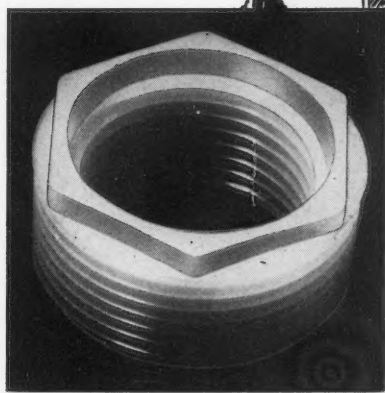
Sodium nitrite was unsatisfactory for inhibiting the corrosion of submerged, inactive strut and stern-tube bearings. Chromate-phosphate inhibitor appeared to be an excellent fresh water protector, but it is not effective in brackish or salt-water systems. Chromate alone, however, provided almost perfect protection for bearings in brackish water when zinc was coupled to the assembly. Some attack on steel members occurred when zinc was absent.

It is tentatively recommended that strut and stern-tube bearings be preserved by filling their protective boots with a solution containing 0.1 percent chromate ions and enough caustic soda to yield a pH of 8-9. The sacrificial zinc half rings should be left in place to increase the protection, but should be replaced when the ship is reactivated.—PDA. 6825



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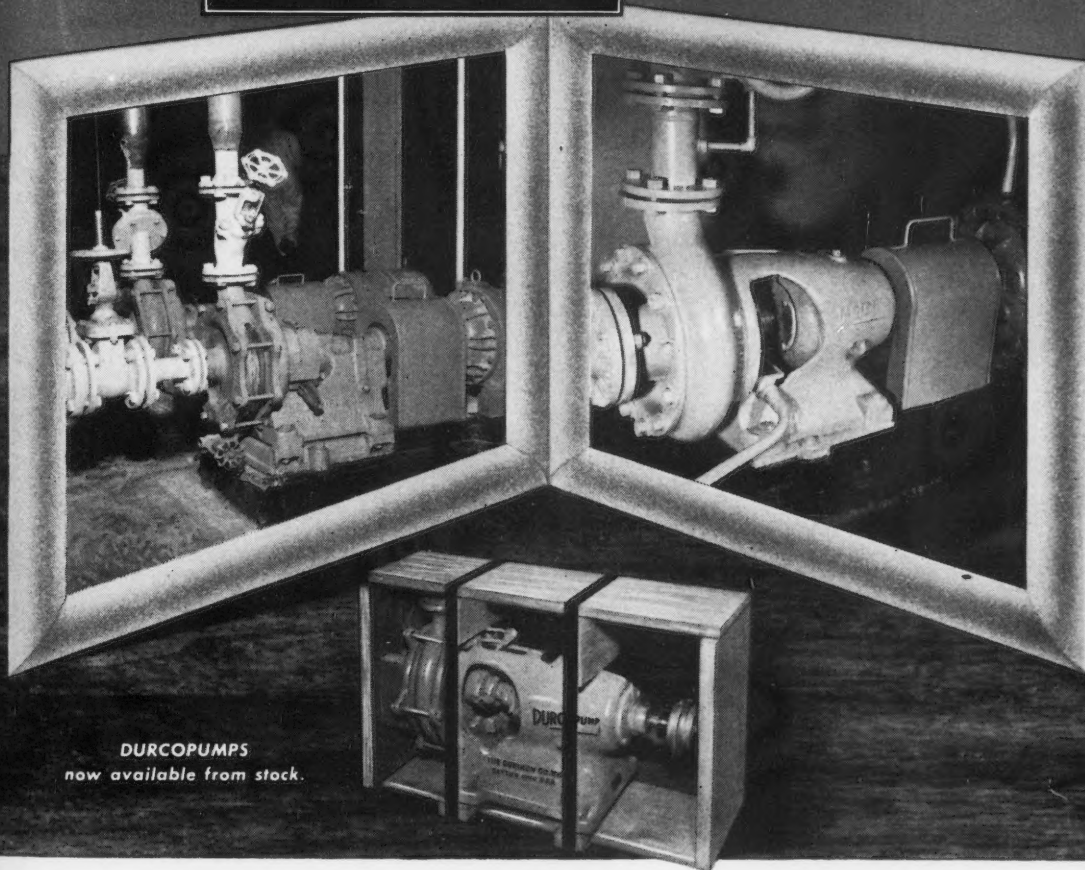
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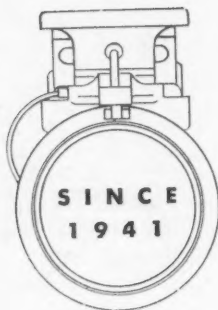
Durco Catalog 54 briefly describes Durco alloys and equipment, and lists detailed bulletins covering specific items.



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